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ANIMAL FLIGHT

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ONE of the most interesting phenomena connected with many of the animals that live on land, as well as some that live in water, is the ability they possess of traveling through the air. The possibility of passage through the air assists the animals in their struggle for existence in four main ways.

Among most insects flight serves merely to distribute the various types more widely and more evenly than would otherwise be possible for these small creatures, thus enabling them more efficiently to make use of the food supply. For instance, you plant some cabbages in your garden. Soon some bright green caterpillars appear upon them. How did they get there? Their mother, a small white butterfly, in flying about discovered them. She was raised on someone else's cabbages, possibly miles away.

The uncountable myriads of insects cruising through the air all summer day and night searching for a place to lay their eggs or for a mate form an important food supply themselves, as their total bulk is very large, and many birds, like swallows, most bats, and many other insects live exclusively upon them.

Hope of escape from enemies alone impels the flying-fish and flying-squid to journey through the air, and many birds use their wings only under similar conditions.

Without the power of flight bees could not store their honey, nor could most birds find sufficient food. The food of vultures and the larger birds at sea, for instance, is widely scattered, and to live at all such birds must be enabled to inspect an enormous area each day.

Before taking up flight in detail let us digress a bit and see how the mind of man has been influenced by the sight of birds and bats and insects passing easily through the air from place to place.

From the very earliest times of which we have a record and among all the human races one of the most strongly marked of

human yearnings has always been the desire to fly, to be able like a bird to leave the earth and to soar higher and higher until all earthly things are left behind. This desire to fly is reflected in the folk-lore and stories of all peoples, and to a greater or lesser extent in all religions.

The most conspicuous soaring bird, the eagle, some variety of which occurs almost everywhere, has been adopted as a national, tribal or family emblem to a greater extent than any other animal or object. You all have heard of the American eagle He figures on the President's flag, on many of our coins, sometimes on our postage stamps, on much of our official letter paper, and on the caps of our army and navy officers. We use the eagle to designate colonels in the army and marine corps, and captains in the navy; and in the army further for all "unattached" officers, and officers of the General Staff. Formerly our generals also wore the eagle, combined with two stars. We used to call one of our coins the "eagle," and more than one hundred of our towns and villages have "eagle" in their names.

While the eagle and the falcon are everywhere associated in the public mind with noble and sublime ideas or aspirations, the creatures that fly by night suggest to all peoples something mysterious and unnatural, and give rise to feelings of awe and dread. The owl is regarded with superstitious fear in many countries, and always is a symbol of something either harmful or at least uncanny. He is feared or distrusted, but never respected. We speak of people sometimes as "wise old owls," though we never apply this term to those we really hold in high regard. The bat is the most characteristic and conspicuous of night-ranging creatures, and in the daytime completely disappears. It is thus quite natural that in the minds of superstitious peoples the bat should be the preeminent symbol of darkness and of mysterious evil. Malignant spirits and the devil are usually shown with bats' wings in contrast to good and kindly spirits and angels, which are depicted with birds' wings.

Optimism, or a tendency to look upon the cheerful side of things, is one of the most fundamental traits of human nature. Wherever we have in our language two contrasting words differing from each other in the occurrence or absence of the prefix "un-" meaning "not," this prefix is always placed before a word of good import and never before a word of evil import, showing that our habit is always primarily to contemplate the good and only secondarily to consider the bad in the world about us. This tendency has brought about a curious transformation in the character of one of the oldest and most universally present of all symbolic animals, the dragon.

In all the ancient Asiatic and European civilizations the flying dragon has played an important part. From very early days, perhaps so long ago as 5000 B. C., to the present in China and Japan, and also in England, as shown on the reverse of the British sovereign, the reptilian dragon with its bat-like wings has preserved an astonishing constancy of form. But, as has been pointed out, a curious transformation took place in Asia Minor and the Mediterranean countries, from Babylonia and Egypt through Assyria to Greece. The wings, which at first had been associated with the fore limbs of the typical dragon and had been bat-like, became bird-like, and then were placed on the shoulders of the lion and of the horse, and finally on man himself, as we see on the great columns of the Greek temples of Ephesus. But all these flying animals are historically descended from the same common stock as the dragons of China and Japan and St. George's dragon of England which still preserve the aspect of reptiles. The Bishop of Exeter regards the Hebrew cherubim as probably originally dragons, and the figure of the conventional angel is merely the human form of the dragon.

Besides the eagles, bats and dragons there are many other flying creatures of less, though still far-reaching, significance as symbols. Such are the dove of peace, the rooster, Egypt's sacred ibis, storks and swans, the "quezal" of Guatemala, and a host of other birds remarkable for their powers of flight or for their beauty. In parts of South America the natives tell you that the gorgeous butterflies called *Morphos* which are only seen high up among the trees on dying enter the ground and there become preserved as emeralds. Flying creatures, especially birds, butterflies, winged mammals and winged serpents, are familiar subjects for more or less conventionalized designs, especially on pottery and totem poles, and coats of arms, but more or less on all ornamented objects and on all types of family or individual insignia.

Of all known kinds of animals almost two thirds can fly, or at least glide through the air, and of land-living creatures the flying sorts number about three quarters of the whole. There are more than 300,000 kinds of flying insects, more than 20,000 flying birds, 600 flying mammals, all but a few of which are bats, possibly 60 flying fishes, and a few flying lizards, snakes and molluscs and perhaps frogs and crustaceans.

Of flying creatures some will fly only at rare intervals and under strong compulsion, and others, like the flying ants and termites, while strong fliers, make only a single flight, after which they discard their wings by cutting them off with their mandibles or by breaking them off at a line of special weakness and again

become ground living. From such as these the amount of time spent on the wing by animals increases step by step until we reach the chimney swifts which fly practically throughout the daylight hours, the insect-eating bats which seem to fly most, if not all, the night, and the albatrosses and related sea-birds which in some localities appear to fly for days and nights together without rest.

The birds are the most familiar of the larger flying creatures. Flying birds range in size from the smallest humming-birds, which are much smaller than our common North American kinds, to the South American condor, with very broad wings, and the wandering albatross with very narrow wings spreading eleven feet or more.

It is a curious fact that the larger the animal the smaller in proportion are the wings. Insects have relatively much larger wings than birds, and small birds have relatively much larger wings than big ones. In the mosquito for each pound of body weight there is a wing area of 4 square yards, 6 square feet, and 105 square inches; in a butterfly of average size each pound of body weight represents a wing area of 3 square yards, 8 square feet, and 87 square inches; in the swallow this is reduced to only 4 square feet and 18 square inches, in the pigeon to 1 square foot and 14 square inches, and in the stork to only 122 square inches.

Not only do the small birds have larger wings than bigger ones, but they move them much more rapidly. The wings of the smaller humming-birds vibrate so fast that it is difficult for the eye to follow them. The wing beats of the sparrow are 780 per minute, of the duck 540, of the pigeon 480 and of the crow about 120.

It was the necessity of finding answers to these questions, why do small birds have to have larger wings than big ones, and why do they have to move their larger wings more rapidly, that made the development of the flying-machine so difficult. The wings of many of the larger birds like the loons and grebes as we see them in the air look ridiculously small, yet these birds can fly for enormous distances at a high speed. It is, however, very difficult for them to get started, and many of them can not rise from the ground at all.

Birds' wings perform two functions: they lift the bird and they drag it forward. We all know that if a light object is thrown it will not travel so far as a heavier object thrown at the same speed. A pitcher can not throw a ball of feathers so far as he can a baseball. If a large and heavy bird can once get going at good speed a relatively small force will keep him going. His body is inclined in such a way that it is kept in the air through its momentum on the principle of a kite. The wings by their motion serve to maintain the speed, but have very little lifting to do. The lighter and smaller

the bird the less is its momentum. Lessened momentum prevents it from maintaining its height by inclining its body against the air. If the wings cease their action the body drops almost instantly. A small bird can approach a perch at full speed and alight upon it with very little voluntary checking of its momentum, but a heavy bird must expend much energy in checking its forward impetus before it can alight with safety. The wings of large and heavy birds serve chiefly to maintain speed, the height being maintained by the momentum and the kiting effect of the body upon the air. The wings of small and light birds must constantly lift as well as maintain momentum—or rather they must constantly lift the bird and pull it forward. This is the reason why the larger the bird the smaller the wings; but the large birds, while they fly with much less effort than the small birds in spite of their smaller wings, have great difficulty in getting started and in stopping. From this it naturally follows that while small birds are found everywhere in all situations, large strong flying birds are mostly confined to the sea and to very open regions where they can arise and alight with safety.

The speed at which birds fly varies very much, but it is not so great as is commonly supposed. You can easily prove this for yourself by pacing them in an automobile along a country road. Only a few birds can fly as fast as the fastest express trains, and none can go so fast as the speedier aeroplanes. Wild ducks and geese have been found to travel on their migrations at a rate of between 44 and 48 miles an hour. Homing pigeons usually travel at between 50 and 55 miles an hour While some swifts may attain a speed as great as 100 miles an hour, most of our smaller birds fly at a rate of between 25 and 28 miles an hour, or at about the average speed maintained by an automobile.

The power of flight and the possibility of moving rapidly from place to place high above such obstacles as water, trees, fences, hills, etc., permits the birds to wander about from season to season, visiting now one region now another in search of food. In the autumn many of our common birds, like the swifts, the swallows, the fly-catchers and the warblers, disappear to the southward, and other birds from the north, like the northern chickadees and nuthatches, the crossbills and the pine and evening grosbeaks, appear in the places they have left. Some birds, like the robin, do not go very far, wintering chiefly in the southern states. Many go to Central and South America, while a few travel enormous distances. The golden plover, which nests in the extreme north of North America, winters in the south of South America. This bird after leaving Labrador ordinarily does not come down again until it arrives at

Guiana, more than 1,700 miles away. It is frequently seen passing over the easternmost of the West Indies at an immense height and has also been seen high in air several hundred miles east of the Bermudas. Coming north it takes a different route, up the Mississippi valley. The eastern godwit, a plover-like bird which nests in Alaska and in eastern Siberia, spends the winter in New Zealand. A great many apparently feeble birds can cover enormous distances without alighting. The little sora rail can cross the Caribbean Sea twice a year without difficulty, and two sorts of cuckoos pass every year from New Zealand to New Caledonia and back over 1,000 miles of sea In many places it is still erroneously believed that the small birds get about by simply perching on the backs of larger birds and being carried by them, so incredible do such powers of flight appear in such weak creatures.

The height at which birds migrate varies considerably. From measurements taken on birds as they crossed the face of the moon at night it was found that the migrations in May were at a height of from 1,200 to 2,400 feet, and those in October at between 1,400 and 5,400 feet.

The flight of birds may be roughly divided into three types, ordinary flight, with almost innumerable variations, such as we see in the common land birds, soaring and gliding.

In the usual type of flight the bird moves through the air with a continual motion of the wings. This is the only type of flight possible in still air, and is characteristic of most land birds, all the smaller sea birds, the ducks, geese, herons and many others.

The large birds progress ordinarily in a straight line, with a slight raising and lowering of the body at every wing beat if the flight is slow, as in the herons. Their momentum and the kite-like effect of their heavy bodies tend to keep them up, and they are very careful not to lose altitude on account of the great difficulty they experience in rising again. Most of the small birds have a wavy or undulating flight which is especially well seen in the finches and the woodpeckers. The rapidity with which they descend when the wing beats cease shows how slight their momentum is, and how essential for them is the great development of lifting power.

Very many of the larger broad-winged birds, as hawks, eagles, vultures, ravens, pelicans, herons, cranes, spoonbills, screamers, etc., are able to circle on motionless wings, gradually rising higher and higher, until they almost or quite disappear. These birds are large and heavy, and compared with small birds their wing area is relatively less. How do they do it?

Birds seldom soar in cloudy weather, nor in cold regions, nor in the winter. Soaring is only possible when the earth is heated by

the sun's rays. When the earth is heated the warm air just above it rises, and if the heating is intense and long continued, strong columns of air rise for very considerable distances, especially over small hills. In these ascending columns of air the birds find a breeze of considerable strength blowing directly upward, the force of the ascending air being sufficient not only to keep them up but to enable them to glide continually downward, yet at the same time rise.

Birds soar in circles in order to keep within the ascending column of air; if they fall over the edge of the column they begin to flap in order to get back into it again. You sometimes see a hawk do this. Soaring is a very popular pastime of the large birds in the drier regions of the tropics, and in some places, as in Egypt, hundreds of birds of many sorts may frequently be seen soaring together. One of the most expert of the soaring birds is the great clumsy-looking adjutant of India, which by many is supposed to sleep while soaring. In the warm regions the appearance of clouds which obscure the sun promptly weakens the force of the ascending columns of air and soon causes all the soaring birds to flap and to return to the ground With us in the north only a few birds, mostly eagles, hawks and vultures, soar, and these only on warm, bright and sunny days.

Many birds, such as partridges, pheasants, quail, tinamous, etc., when startled fly diagonally upward with great violence to a considerable height and then glide downward to a place of safety, and most of the larger birds glide more or less when approaching the ground or a perch. This gliding has been developed not only in the direction of soaring as just described, but also into a combination of gliding and soaring—mostly gliding—which is characteristic of the flight of a very large number of sea birds. Many of these are such adepts that they can glide all day and never flap their wings. The albatross is the most marvellous of all the gliders; he courses back and forth over the waves, always keeping close to the water, for hour after hour with his long narrow wings extended almost motionless.

Waves are rows of little hills stretching across the wind. The wind on striking one of these rows of hills is deflected upward with considerable force, and it is by taking advantage of these strong updraughts that the albatross is able to glide perpetually. When flying with the wind the albatross rapidly loses altitude, so he must frequently turn back into the wind again to allow the updraughts from a few waves to raise him anew to the required height. His course to leeward, or down the wind, is therefore a series of loops with long gliding intervals between, and his course across the wind

is a similar series of loops. As a steamer plows its way along the air behind it is drawn under the stern with such force as to rise into a column of considerable height just behind it. On this column the albatrosses frequently balance themselves, appearing perfectly motionless except for the movement of their heads, traveling at the same rate as the ship, being kept up and drawn along through power originating in the engines of the ship itself. Other sea birds, especially gulls, are fond of balancing themselves on this air column.

In a dead calm the albatross is a pitiable object. He sits on the water, rarely attempting to fly. He can only rise with the greatest difficulty after a prodigious amount of splashing and flapping, and his very slow, heavy and laborious progress is by an alternation of clumsy flapping and gliding, suggesting the flight of an awkward lazy pelican, of which he soon tires, in fact he is all but helpless. The albatross, the most wonderful flier among the birds, is kept in the air not by any efforts of his own, but by a combination of strong wind and waves, and hence the albatross is exclusively a bird of the windier regions of the oceans. He can only exist where the wind is always strong and the waves are always high The calm belts of the tropics form an impassable barrier for him, and he can not fly for any appreciable distance over land. The stormy southern oceans and the equally boisterous north Pacific are his home; but no one kind exists in both these places. He can not live in the tropic calms, nor in the relatively calm North Atlantic.

Quite a number of smaller sea birds ranging in size from the giant fulmars down to the smaller shearwaters have the same habit of flight as the albatross and are quite as good fliers as is he; but for the most part they are much smaller with broader wings and can fly well in winds so light that they would not serve the albatross at all, and they can also fly well, though with much flapping, during calms. When a strong wind strikes a cliff a considerable amount of air is deflected upward forming a column or wall of air for a considerable height above the top of the cliff. Such a mass of rising air is a favorite playground for birds which soar above it just as other birds do in the columns of warm air rising from the hot tropical lowlands.

At Agattu Island in the western Aleutians where the sun very rarely shines—there is no record that any one ever saw the sun there—but where the wind always blows there is a cliff near the anchorage on and near which all sorts of birds abound. When the wind blows against this cliff the air above it becomes filled with birds, some merely flying back and forth, like the puffins, murres and guillemots, but others wheeling and soaring like hawks. Most con-

spicuous among these soaring birds are the geese, cormorants and ravens, birds which ordinarily we never think of as indulging in diversions of this nature The gulls, too, are very numerous, but as the gull is an expert balancer and glider it seems only natural that he should be here.

In mountainous regions there are always strong updraughts of air, both because of the upward deflection of the winds and because of the warming action of the sun's rays. Mountainous regions therefore are especially adapted to the development of the soaring habit. The uprush of air due to deflection of the winds makes soaring possible on cloudy days, and in the far north and south under conditions which would prevent it on flat land where the only updraughts are the result of heating.

Mountainous regions always harbor many soaring birds. As a fruit-eating bird would derive no advantage whatever from the practice of soaring, all fruit being far more visible from below or from the side than from above, and also stationary, the soaring birds of mountainous regions are mostly predaceous or carrion feeders, or a combination of the two, or quite omnivorous. They include eagles, vultures, hawks and ravens, and because of the great advantage that they have in being able with a minimum of exertion to survey a vast amount of territory and thus to detect a maximum amount of food, the largest of the flying birds, such as the condor, the Californian vulture, the lammergeier, the griffon and brown vultures, all the larger eagles and the ravens, live in mountainous lands. The buoyant effect of wind blowing against a hillside is easily appreciated by watching a turkey buzzard quartering back and forth in his peculiar seesawing way without flapping his wings, yet without losing altitude.

Among the birds we find all possible gradations from birds like the albatrosses, frigate-birds and chimney swifts, which are almost always on the wing, through the majority of flying birds to such forms as the tinamous and rails, which very seldom fly, to others, like the ostriches, that can not fly at all, and finally to those queer fossil birds with no trace of wings whatever.

The flightless birds fall into three categories: Birds large, powerful or swift enough to outfight or to outdistance any enemies, like the ostriches of Africa and Arabia, the rheas of South America, the emus of Australia and the cassowaries of Queensland, New Guinea and the Moluccas; sea birds frequenting regions where there are no beasts of prey, like the penguins, the great auk and the flightless cormorants of the Commander Islands and the Galapagos; and land birds living in regions from which predaceous beasts are absent, such as the dodo of Mauritius, the solitaire of

Rodriguez, the kiwis of New Zealand, the flightless rails of Oceania, etc. Unless protected by most rigid laws such birds are doomed whenever man penetrates their territory; if large they and their eggs are eaten, and if small they soon become the victims of the dogs, cats and rats which man always carries with him in his wanderings. Thus the Commander Island flightless cormorant, the dodo and the solitaire and the great auk have disappeared, and some of the other flightless birds are much reduced in numbers.

The penguins of the southern hemisphere and the great auk have their wings so modified as to form long and powerful fins with which they swim, after the manner of sea turtles and contrary to the habit of most water birds which swim with their feet only, the wings being used but little if at all. The rheas are peculiar in sometimes running with one wing raised like a sail, no one knows why. The ostriches flap both wings in running more or less. In the emus, cassowaries and kiwis the wings are extremely small.

The ducks, geese, swans and flamingos for part of the year are flightless, for when they moult all their wing feathers are lost at the same time, not one by one as in the case of other birds, and they can not fly until these grow out again. But as these birds are inhabitants of vast marshes, swamps, lakes, isolated reefs and islets, or remote regions where their enemies can not follow them they do not suffer from the temporary loss of flight.

The bats vary much less in bodily form and in the shape of their wings than do the birds, and their flight is much more uniform. None of them soar, and none of them glide. Unlike birds, most of them are all but helpless on the ground, though a few of the small ones can run almost as rapidly as mice. Certain of the smaller bats with long and very narrow wings fly so much like chimney swifts that they are easily mistaken for them, and the resemblance is heightened by their somewhat similar chatter. The largest bats, the flying-foxes and other fruit bats fly like crows.

Nearly all bats, though not rapid fliers, are wonderfully quick on the wing, twisting and turning and even doubling in their flight with an agility rarely seen in birds. For most of them the object of their flight is the same—to enable them to capture insects. Some of them, all large slow-flying ones, eat fruit, one, also large and slow-flying, catches fish, while a few others catch small birds or suck the blood of the larger animals. But the great majority feed on insects, and so the same style of flight is equally suitable for all and there is no need for them to specialize as the birds have done. Soaring and gliding would be of no advantage to the bats, for they must seek their food in those still and quiet regions where night insects fly the thickest; ability to turn quickly is their chief require-

ment. Most bats fly between 10 and 20 feet above the ground, high enough to avoid the bushy and herbaceous growths, and low enough to bring them within the region most frequented by night-flying moths and beetles. They avoid the forests, but are abundant in clearings, in open glades, and on the borders of woodlands. The large fish-eating bats fly just above the surface of the sea like petrels, coursing back and forth in their search for small fishes. In the daytime the bats mostly retreat to the dark recesses of caves or hollow trees, or enter barns or houses, though some of them, like the flying-foxes, suspend themselves from the limbs of trees. Their enemies are few; they are sometimes caught by hawks and owls, and a few small hawks mainly feed upon them.

In the past there lived numerous reptiles with bat-like wings called pterodactyls. These were of a great variety of sizes, from smaller than a sparrow to huge creatures with a spread of twenty feet or more. Their long jaws were armed with formidable teeth, and they must have been very uncomfortable creatures to encounter.

All the remaining sorts of flying animals except the insects are gliders with the surface of the body increased in various ways so that they are able greatly to prolong their leaps by supporting themselves upon the air Except for the fishes these are all climbing animals inhabiting the forests, and except for the reptiles they are active only at night. The reason for this is that in order to glide successfully they must attain a considerable height, and during a long glide they are practically helpless; they can not dodge about and twist and turn as do the birds and bats, so that if they came out in daylight they would run great danger from the hawks.

One of our very common animals, though one not often noticed because of its strictly nocturnal habits and on account of its small size is the little flying squirrel. Flying squirrels live everywhere in northern forests, in North America, in Europe and in Asia, and in the East Indies some are found which are almost as large as cats.

In the flying squirrels the skin along the sides of the body is extended outward in a broad flap stretching from the fore to the hind legs and supported by a long bone arising from the base of the hand, and the tail is flattened and very dense instead of rounded and loose as in the other squirrels. Supported by these strips of skin the flying squirrels are enabled to make enormous leaps from tree to tree, covering sometimes as much as one hundred feet; but on the ground they are clumsy and awkward.

Our flying squirrels are so retiring and so small that in many of the places where they are commonest only a very few people know of their existence. They spend the day in holes in trees from

which they emerge only after sunset. But they are rather sensitive, and they usually may be frightened out of their holes by tapping the trunk of the tree in which they live. However, it is one thing to get a flying squirrel out into the open, and quite another thing to catch him. He comes from his hole like a flash, climbs to the top of the tree, keeping the trunk between himself and the observer, and launches out into the air. At first he falls diagonally and usually quite abruptly downward, his course gradually curving outward until his body is parallel with the ground, when he suddenly shoots upward and lands on the trunk of another tree, instantly disappearing around the trunk and mounting to the upper branches either to hide or to launch forth again He is an expert in the art of keeping a tree between himself and his pursuer, and because of the difference in color between the upper and under sides of his body he sometimes seems in the mottled shadows of the woods to disappear while in full flight. As he is not very much larger than a mouse he can hide very easily, and altogether he is quite an elusive creature.

In the forests of the East Indies there lives the flying maki, or *Galeopithecus,* an animal very different from the flying squirrel, but resembling it in its gliding flight. The parachute like extensions of its skin are relatively larger than those of any other gliding animal, and it is able to "fly" for more than two hundred feet. New Guinea and Australia, especially New South Wales, are the home of the flying opossums, some of which are among the smallest of all known mammals, measuring scarcely five and a half inches in length with the tail making up more than half of this. These little creatures are more expert on the wing than the flying squirrels or the flying maki, and are able to twist and turn to an astonishing degree. The great forests south of the Sahara are inhabited by the flying mouse, a little creature with the habits of the flying opossums

In the East Indian region are found the flying lizards. These are rather small lizards with a broad thin semicircular projection like a broad fin stiffened by processes from the ribs on either side of the body by means of which they are enabled to glide through the air after the manner of the flying squirrels. Like the flying squirrels they glide obliquely downward until near their objective, when they turn and finish their flight with a short upward glide. Some of the Malayan geckos or singing lizards have the body expanded somewhat after the fashion of the flying lizards, but the expansion is not stiffened. These have been supposed to fly, but Dr. Stejneger believes that the broadening is merely an adaptation for concealing them by obscuring their outline and that they can not really fly.

Certain climbing snakes of the Malayan archipelago are able without any special adaptations of the body to glide through the air like a missile from one tree to another over a considerable distance. These flying snakes have the under side of the body marked with deep longitudinal grooves, and during the leap they hold themselves motionless like a rigid stick.

In the forests of Sumatra, Borneo and Java there lives the flying frog, a sort of tree frog with especially elongate toes and fingers between which are greatly developed webs In jumping from tree to tree this frog is said to spread its feet and thus to glide on the expanded membranes much after the manner of the flying squirrels, covering enormous distances. Most tree frogs are prodigious jumpers, and there seems to be some doubt whether this one is really helped much by its large feet.

We all know that certain kinds of animals are only found in certain regions of the world, tigers only in Asia, giraffes and zebras only in Africa, kangaroos only in Australia, musk oxen only in the arctic regions, armadillos and sloths only in tropical America, etc. In the same way certain habits affecting many kinds of animals may be confined to particular localities. Terrestrial flying creatures other than insects, birds and bats are almost exclusively confined to the East Indian region, where we find flying squirrels, flying makis, flying lizards, flying snakes and flying frogs. Outside of the East Indies there are only three types of flying animals, the flying squirrels of Asia, Europe and North America, the flying opossums of Australia and New Guinea, and the flying mice of Africa, only one sort of flying creature in each place. Except for birds and bats and insects there are no flying animals of any kind in South America.

But on the other hand the habit of hanging by the tail and of using the tail as an organ of prehension and of locomotion is almost exclusively confined to tropical America, where it is characteristic of many animals in many very diverse groups, as monkeys, carnivorous animals, opossums, rats and porcupines. Why should this be so?

Let us now briefly survey the insects, the most numerous of all the flying creatures. In their younger stages all insects are wingless, but when adult most insects can fly. Of all of them the tsetses and some of the bird flies fly the longest in proportion to their length of life. These flies are born as pupae or as larvae just ready to transform to pupae from which adults emerge. They do not feed as larvae or as pupae, and their adult winged existence is correspondingly prolonged.

In many insects the flying stage is very short. For instance the seventeen year locust, or "periodical cicada" as the entomolo-

gists would prefer to have us call it, spends only about one nine hundredth part of its existence in the winged state, and it does not fly much even in that short time; while in some may-flies, which lack a mouth and therefore can not feed, the flying period is less than one one thousandth part of their whole life Thus if we were may-flies flying would be possible for not more than twenty-five days out of a normal life. In most insects the flying stage is rather short compared with the whole length of life, and in very few is it so much as a quarter of their whole existence. In most flying insects both sexes fly equally well, as among the birds and bats, but in many the larger and heavier females are much less expert than the males, and in some the females can not fly at all, the wings being much reduced in size or even absent altogether.

Let us here repeat that the relative size of an insect's wing is much greater than that of a bird's wing. An insect is so light that it has no momentum, so that the wings must continually pull the body forward as well as lift it. Since there is no momentum the lifting and the pulling must be as nearly continuous as possible, so that the wing motion of insects is incomparably more rapid than that of birds The common cabbage butterfly moves its wings at the rate of 540 strokes per minute; the sphingid moths at the rate of 4,320 beats per minute; the wasp at the rate of 6,600 beats per minute; the honey bee at the rate of 11,400 beats per minute; while the wings of the common house-fly vibrate at the rate of 19,800 beats per minute.

The difference in the relative area of the wings between a mosquito and a stork may be appreciated when it is realized that if a stork had wings proportionately as large as those of a mosquito they would have an area of almost twenty-eight and a half square yards, and an expanse of more than twenty-five feet.

Of all the insects the larger dragon-flies, so common about the ponds and streams in which they live when young, are the swiftest on the wing. One sort of these (*Austrophlebia*) was timed by Dr. R. J. Tillyard, who found that it covered between 80 and 90 yards in three seconds, which means that it was flying at the rate of nearly 60 miles an hour.

Dr. Alexander Wetmore has recently determined that the great blue heron flies at the rate of 28 miles an hour, the red-tailed hawk at 22, the flicker at 25, and the raven at 24, so it is evident that the larger dragon-flies have little to fear from birds, though many of the smaller, weaker ones are eaten by them. Such birds as travel at a rate approaching that of the large dragon-flies often become victims of their speed. Being heavy, they can not turn aside to avoid danger; put a net suddenly in front of them, and into it they go.

The Esquimaux catch thousands of sea-birds annually in this way by intercepting them as they fly along the shore. But the dragon-fly is different. Put a net in front of him and he instantly shoots off sideways, or up or down, or even doubles on his course. He is so light that he has no appreciable momentum and therefore he can twist and turn about in a way quite impossible for any bird.

There are many different kinds of dragon-flies; all of them eat other insects which they catch upon the wing. They have many different kinds of flight, darting, skimming or soaring about in search of their more or less nimble victims. But the soaring, so-called, of a dragon-fly is a very different thing from the soaring of a bird; at first sight it seems to be the same, but if you watch closely you will see that the dragon-fly keeps his wings in motion almost all the time.

Dragon-flies have various relatives, like ant-lions and lace-winged flies, which, strange to say, are slow and feeble fliers; they are awkward and clumsy in the air and they give you the impression that their wings are too big for them.

The dragon-flies and their relatives are the only flying creatures which have two functional pairs of wings acting independently and placed one behind the other as in the original Langley aeroplane.

The beetles, like the dragon-fly, have two independent pairs of wings, but the wings of the anterior pair are modified in such a way that when the beetle is at rest they fit closely down over those of the posterior pair, which are folded up beneath them. In flight these anterior wings are held rigidly extended at various angles, the hinder wings doing all the work. It is possible, however, that in some cases the anterior wings may serve the purpose of a pair of planes, assisting in keeping the insect in the air, though many beetles fly just as well if they are removed, and in some excellent fliers, like the devil's coach horse, they are so small as to be quite functionless.

As a rule the flight of beetles is slow and clumsy, especially of the larger kinds which fly only at night and rather high so as to avoid the shrubs and bushes. Some, like the tiger beetles which in the spring we see running rapidly about on the bare ground in their hunt for smaller insects, are quite expert in turning and twisting in the air, while very many can not fly at all.

The grasshoppers, locusts, crickets and their allies have the fore wings stiff and tough, not used in flight, and the hind wings membranous and closing like a fan instead of being folded on a hinge in the front margin as in the beetles. In most the flight is weak and rattly, and very many can not fly at all. But some, like the migratory locusts, are strong fliers.

Regarding the speed of grasshoppers I quote a letter from Mr. Andrew N. Caudell:

> In early August of 1920 while studying economic species of grasshoppers in Centennial Valley, Montana, I had an excellent opportunity of observing the speed at which *Cannula pellucida* flew. By noting individuals that were flushed by the roadside by the automobile in which I was riding I chose ones that flew parallel with the machine, which was driven at the rate of 15 miles per hour. I found that under those conditions the rate of flight for this species is almost exactly 15 miles per hour. In long flights, especially with the wind, the rate may be much faster, as J. R Parker has estimated the speed of migratory swarms to be 30 miles per hour. That appears to be too high an estimate, judging from my experience with the insects' flight when flushed by the automobile. Mr. C. L. Corkins gives the rate of flight of ***Melanoplus*** *atlantis* as 20 miles per hour, the rate being determined by the same method I used with *Cannula*, that is by observations made from an automobile moving at a given rate

The flies properly so called, the house-fly, the blue-bottle, the horse-fly, the crane-fly, the black-fly, the mosquito, the gnat, the midge, the robber-fly, etc., have only two wings, the hinder pair being replaced by curious knobbed structures known as balancers or halters which are apparently sensory and in some kinds possibly stridulating. It is interesting to note that while in the beetles the hind wings only are used for flight, in the flies these have completely lost their function as flying organs, the flight being effected entirely by those of the anterior pair.

While a few flies are wingless, or have very small and useless wings, most of them are expert fliers. They can twist and turn and dodge and hover and dart quite as well as the dragon-flies, and though most of them are not very speedy, some, like the robber-flies which feed on other insects, are by no means slow. There are more different kinds of flight among the flies than among any other kinds of insects, ranging from the direct, swift and powerful flight of the robber and horse-flies and the twisting and dodging flight of the lesser house fly to the dancing of the gnats and the hovering and darting of many syrphids and bombyliids. These last are commonly seen suspended and apparently motionless in the air a few feet above the ground over woodland paths; if startled they dodge away so rapidly that frequently the eye can not follow them.

In most other insects the four wings when extended function as a single pair, the hinder edge of the fore wings being hooked to the front edge of the hind wings in various ways, as in the butterflies, moths, bees, wasps, etc. In some of the butterflies and moths the wings are enormous in proportion to the size of the body.

Very few insects have a definitely developed tail capable of being used for steering; some of the hawk moths have movable tufts of long hairs on the end of the body which may be used for this

purpose, and one of the small parasitic wasps has a very remarkable tail of two thin plates crossing each other at right angles in the middle. Many butterflies, like the swallow-tails, and a number of moths, like our common luna and its various Asiatic relatives, have the hind wings produced into so-called tails, which may be very long; in some species only the males have them. In other insects, as in certain ant-lions, the fore wings may be normal, but the hind wings are very narrow and extremely long and more or less twisted.

In all flying animals the steering is done chiefly or entirely with the wings. Many bats are tailless, but they fly quite as well as the bats with tails. The long-tailed birds, like the cuckoos, forked-tailed, scissor-tailed and paradise fly-catchers, long-tailed trogons, tailor birds, emu wrens, lyre birds, turkeys, curassows, pheasants, etc, are relatively weak fliers, while all the birds remarkable for very long flights, like the plovers, curlews, godwits, ducks, geese and swans, or for long-continued gliding flight, like albatrosses and shearwaters, are short-tailed Soaring birds to increase the lifting surface mostly have large broad tails, just as they have very broad wings. Most long-tailed birds are small; if large they are ground living; if good fliers the elongated feathers of the tail are reduced to two which are usually very narrow, the two outermost in the swallows, terns, some flycatchers, some humming-birds, etc, the two central in the macaws, lories, tropic-birds, other flycatchers, other humming-birds, etc Birds which pounce upon their prey or feed after the manner of bats, such as most hawks, falcons, kites and owls, goatsuckers, night-hawks, whippoorwills, most flycatchers, etc., have large broad tails, and undoubtedly these assist them in turning abruptly downward, upward or sideways.

Most creatures when flying make more or less noise, and many have special sounding organs connected with their wings. The bats all make a low swishing sound which is only audible for a short distance. The wings of most birds make a swishing sound which varies from the droning hum of the humming-birds to the loud dull rustling roar of the large vultures, swans, geese and ducks. These sounds are merely the result of the rapid passage of the wings through the air. In some ducks, on that account commonly called "whistlers," the wings make a loud shrill whistling noise in flight which on a still day may be heard for a very considerable distance; this is due to the vibration set in motion by parts of certain of the wing feathers. The passage of most pigeons and doves and of some other rapid fliers through the air is also accompanied by a more or less distinct whistling. In addition to this pigeons and doves on rising suddenly from the ground usually make a clapping or rattling noise with their wings; but if not startled they often rise

quietly. The flight of some birds, especially of the owls, is strangely silent, apparently so as not to interfere with the detection of the slight sounds made by the creatures they are seeking, by which means they find them.

The droning of beetles and the buzzing and humming of flies, bees, wasps, mosquitoes, etc , are known to every one , some insects, like the large cockroaches in the tropics, fly with a loud rattling noise, and some, like certain butterflies and grasshoppers, when on the wing make chirping or clicking sounds at will by means of a special mechanism connected with the wings

The flight of the large slow-flying moths, like our common cecropia, polyphemus, promethea and luna, like that of the owls, is almost noiseless; and it is fortunate for them that this is so as otherwise they would soon disappear through extermination by the small owls and by the bats.

Many flies can hum or buzz quite as well with the wings cut off as with them present, apparently through the action of the halteres which in this case appear to be wings transformed into singing organs The song of the crickets, locusts, grasshoppers, katydids and similar insects is produced by the forewings, parts of which are modified into very perfect sounding organs operated by the rubbing of the wings together or by the long hind legs.

The song of the cicadas and their allies, though it sounds much like that of the crickets and the locusts, at least like that of some of their tropical representatives, is not produced by the wings but by a special apparatus on the under side of the body. In some kinds the piercing shriek they give can only be compared to the whistle of a steam engine, and may easily be heard on a calm day four miles or more.

The wings of insects are mere outgrowths from the body wall, quite unconnected with the legs. They are thus comparable to the side extensions of the flying lizards and to the cobra's hood. In many groups, especially in the moths and butterflies and in many flies, like moth-flies, they bear numerous broad scales somewhat resembling the feathers of a bird; in others they are often sparsely hairy like a bat's wings.

Except for bats all the flying mammals are tree-living climbing creatures, and in them the wing membrane is stretched between the legs. In the bats and birds the wings are an adaptation from special climbing organs, somewhat as suggested by the long arms of the spider monkeys In the bats the flying surface is formed by broad areas of skin stretched between immensely elongated fingers and extending to the hind legs as in the ancient flying reptiles and in all other flying mammals. In the birds the flying surface is

made up of long feathers which are outgrowths of the skin of the long front limbs. With their very long arms the monkeys and the lemurs climb with great rapidity through the forest trees. With their very strong and suitably modified front limbs the bats and birds in much the same way climb through the air. One bird, the hoactzin, when young climbs actively about the bushes with its fore limbs which, as in many other birds, have claws; when fully grown it climbs through the air like any other bird.

The wings of flying fishes do not differ from the corresponding fins of other fishes except in their greater size.

Besides the animals which fly by their own efforts there are many others which at some period of their existence, usually when young, are wafted through the air without the aid of flying organs just as the seeds of many plants are blown about.

Chief among these are the flying spiders. Many different kinds of spiders have hit upon this means of getting from place to place. It is usually, though not invariably, the young spiders that do this, and the phenomenon is best observed on warm and comparatively quiet autumn days when there is a good updraught of wind. The spiders climb to the summit of some object, such as a stick, fence post, plant or stone, and release a fine thread or several of them, or sometimes a tangled mass of threads. When the pull of the ascending air upon the threads is strong enough the spider lets go his hold and floats away One of the most sedentary of the spiders, living as a rule under stones, sticks and other objects, has adopted this means of getting from place to place, and it is also used by spiders of many other kinds. Occasionally spiders try to rise in an adverse wind, and then their threads instead of rising are blown onto the ground or onto the nearby plants sometimes forming enormous sheets of silk. These sheets of silk may later be lifted up and blown away, coming down in some distant place as a so-called gossamer shower.

Many insects, especially the smaller ones like aphids, can fly just well enough to keep up in the air without making much of any progress. These form a connecting link between creatures that fly by their own efforts and those that are wafted by the winds from place to place. Many caterpillars, such as those of the gypsy moth, are when very small widely distributed by the strong winds of spring.

When a pond dries up many of the small water creatures either condense themselves into the smallest possible space and surround themselves with a tough shell, or form highly resistant eggs and die. These capsules and eggs are picked up by the wind and carried for long distances; in fact the air, even for hundreds of miles

at sea, always contains besides mineral dust, particles representing the remains and the living spores and seeds of animals and plants. This is why any puddle of water, no matter where it is, on the ground, on a roof, or in hollows in the branches of tall trees, swarms with life almost immediately after its appearance.

Among the animals on land which do not fly many of the larger ones have certain adaptations which enable them to use the resistance of the air for their protection. Leaping animals that live in tree tops, like the lemurs and the smaller monkeys and most squirrels very often have great outgrowths of long hairs which serve to minimize the shock of landing. The so-called flying-monkey of the upper Amazons looks when it leaps much like a flying squirrel, but it has no extended membranes on its sides, great tufts of long hair simulating these.

The cobras when they strike raise themselves high above the ground on the tail and hinder portion of the body, and then fall forward They do not shoot the head out suddenly as do our rattlesnakes. As they fall forward their broad hood acts as a wind brake and delays the body so that the danger from the fall is minimized. In the frilled lizard of Australia which runs very rapidly on its hind legs with the body more or less erect the frills act as an air brake in the same way.

We have now considered all the flying animals that live on land; but in addition there are some that live in water. Chief among the aquatic flying creatures are the flying-fishes which are abundant in all the warmer seas. These fishes are one of the great wonders of the oceans. Leaving the water with a tremendous rush, the large side fins, which in some kinds reach a length equal to two thirds the total body length or even more, are rigidly extended like the wings of an aeroplane and held in this position by powerful muscles. Supported by these great fins the fish is able to go for an astonishingly long distance, and in a strong wind to rise to a considerable height. When its momentum is expended it falls back into the water, or sometimes takes a fresh start by the vigorous action of its tail, the lower and larger part of which is dipped beneath the surface.

The old question, which was created first, the hen or the egg, is replaced at sea by the equally old question, do flying-fishes really fly, or do they not? This question is always being discussed somewhere or other and has been under continual discussion ever since man first sailed the seas. Every sailor knows that the wings of flying-fishes move, for he has seen them move and heard them hum; nothing but the fish could move them, and therefore he says that the fish does move them, and consequently flies after the man-

ner of a bird. Others say the flying-fishes do not fly because they can not; the muscles about the base of the wing-like fins, though large and strong, are merely used to keep the fins extended and serve no other purpose. The sailor retorts that this is pure theory and not to be considered in the light of the observed fact that the wings are actually moved. Both sides, the realists and the theorists, support their views with all sorts of arguments from the realms of marine biology, anatomy and marine mythology, and the discussion finally comes to rest exactly where it started. No real sailor will admit that flying-fishes can not fly, while no landsman will admit they can.

In their contentions both are partly right. It has been shown that flying-fishes fly so far that their flight can not be explained on the basis of the original impetus alone, no one who has seen them at close quarters can doubt the movement of their fins. Therefore, while flying-fishes are mainly gliders, their flight to some extent is aided by the movement of their fins. While flying-fishes jump from the water and glide away right and left before a steamer, a small boat does not disturb them in the least. If you are out in a small boat there may be thousands of them about you and you may never learn their presence. Through this peculiarity they are easy to secure

When the trade wind is blowing the surface of the sea is covered with little waves from which the sunlight is reflected so that a relatively small amount penetrates beneath the surface. While to us the ocean looks especially bright and sparkling in a brisk breeze, beneath the surface it is dark and gloomy, for all the myriads of sparkles that catch our eye mean a corresponding amount of light rebounding from the surface instead of penetrating. It is under these conditions that the fishermen go forth to catch the flying-fish. For this they must go for a long distance, until the shore begins to disappear, for the flying-fish is preeminently a creature of the high seas and well knows the dangers that lurk in shallow water. Having arrived at what he considers a suitable location, the fisherman throws overboard some oily matter, usually, because most available, some half decayed flying-fishes from a previous catch. The oil spreads out and forms a relatively quiet area about the boat; the waves within this cease to sparkle, and the surface here takes on a dark and gloomy aspect. But looked at from below just the reverse occurs; the stilling of the wavelets results in the formation of a brilliantly lighted patch. Though previously no flying-fish at all were visible, the water about the boat now teems with them; they have come from all directions attracted by the bright spot on the surface. With frantic haste they are scooped

into the boat with dip-nets—they do not attempt to fly—until suddenly they all vanish. Immediately several large hooks on strong lines are thrown out, each with a flying-fish as bait, and one or more is often seized by a dolphin or a shark, whatever it was that frightened the flying-fish away. The oil has now become so scattered that its effect is lost, and the fishermen sail away to try their luck elsewhere.

There are three little flying-fishes that live in fresh water, one, the most expert of them, in the rivers of western Africa, and the other two, which are only able to make short flights, in eastern South America. Flying-fishes are no new creation, for as far back as the Triassic seas there were at least three kinds, in some respects much better adapted for flight than are those of the present day.

Brief mention must be made of those so-called flying-fishes that do not fly, chief among which are the flying gurnards. In these fishes the side fins are enormous, and often very brightly colored, and look as if they could be used in flight. But these are sluggish bottom-living fishes found only in shallow water near the shores and more or less like sculpins in their habits. They never leave the water except perhaps and very rarely in a short clumsy jump. The bat-fishes of the tropics, which are enormous rays, like many other fishes will sometimes leap above the surface but they do not fly.

In some parts of the ocean the passage of a steamer will frighten from the water objects which at first sight look like flying-fishes, of about the same size but thinner and more cylindrical. When these things leave the water instead of scattering as does a company of flying-fishes they always keep together in a close formation maintaining the same distance from each other, and all the members of a company always drop into the sea at the same time. I first saw these off northwestern Africa and it was the close formation that attracted my attention. Their flight is rather short, and it was difficult to catch them with the telescope; but when I did I found that they were cuttle-fish or squid, flying tail first, and easily distinguishable from the fishes by their large dark eyes at the wrong end.

The only other flying thing at sea, except the birds, and sometimes bats on their migrations, is a small crustacean that lives in great numbers at the surface in some places. This little creature often jumps clear of the water, and is said to prolong its leap by gliding through the air after the manner of a flying-squirrel.

KELP AS AN AGENT FOR THE CONTROL OF GOITER

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PREVALENCE AND INCIDENCE OF GOITER

GOITER is a disease seemingly without historic, geographic, topographic, climatic, racial, genus, sex or age restrictions. It was known to the Greeks at the time of the Greek Empire. To-day it is reported from Asia, New Zealand, Africa, the Near East, the various European countries, North and South America, the United States, from all the states and particularly throughout an area extending in an east to west direction from the New England States to the Pacific Coast and Alaska, thus completing the entire circuit of the globe It is reported from the tropical islands of Asia to the cold upper valleys of the Himalayas, from Florida to British Columbia, from the seashore to the highest mountains. Among races, it is observed among the negroes of Africa, one extreme, throughout the various races, to the most civilized. It is found likewise among most of the animals retained under those conditions which make observation easily possible (the domestic animals), some of the fowls and even frogs and fish. It finds its victims among both males and females, the young, the middle-aged and the old.

The common impression is that the prevalence among women and girls is about six times that among men and boys. However, it appears that in foci of severe endemic goiter, sex plays little part.[1] Geographically, incidence varies over wide limits, from a very small figure to almost 100 per cent.

The region of greatest endemicity inhabited by a white race is Switzerland. Here the incidence in certain localities is reported as 100 per cent., where it has been attributed to the drinking of "snow water." Klinger[2] reports a specific incidence among a school population of 82 to 95 per cent. Equal prevalence is reported from certain valleys of the Himalayas.

The incidence in the United States reaches 25 per cent. (among females) in a number of instances and covering a large portion of

[1] Hayhurst, "The present-day sources of common salt in relation to health and especially to iodine scarcity and goiter," *J. Am. Med. Assn.*, *78*, 18 (1922).

[2] As quoted by Marine and Kimball, *loc. cit.*

the thickly inhabited regions of the country. The distribution of cases among the men of draft age of various racial, social and industrial classes, the only comprehensive survey made to date, is shown in the following table:[3]

TABLE I

INCIDENCE OF GOITER AMONG DRAFTED MEN

Group	Total cases	Ratio per 1,000	Ratio per 1,000 cases, in groups
Agric., native, white, north, 73 per cent. plus	1,866	9.24	17.46
Agric., foreign and native, white	3,490	11.91	22 61
Agric, native, white, South	1,443	3.36	6 50
Agric., negro, 45 per cent. plus	317	1.76	3 19
Eastern manufacturing	926	4.15	6 98
Commuters	299	4.03	7.49
Mining	1,203	12 57	22.11
Sparsely settled, 3 or less per sq mi.	747	16.53	28.85
Desert	44	3 64	5.44
Maritime	42	2 09	3 05
Mountain	775	14.70	25.71
Mountain whites	539	7.40	13.04
Indian, sparsely settled	79	2 48	4.68
Mexican, sparsely settled	35	1.26	2 68
Native white, Scotch origin	154	2 84	6.00
Russian, 10 per cent. plus	387	10 18	17.21
Scandinavian, 10 per cent.	2,865	18.25	33.59
Finns, 10 per cent.	364	26.71	51.41
French Canadian, 10 per cent. plus	109	1.18	1.73
German and Scandinavian	1,446	14.66	28.33
German and Austrian, 20 per cent plus	1,048	10.55	20.63
German and Austrian, 15 per cent. plus	3,747	10.66	19.75

From an examination of available data relating to incidence the following generalizations may be drawn:

(1) Goiter occurs in all parts of the United States, no locality being exempt.

(2) Regions lying close to the Atlantic and Gulf Coasts are relatively free of goiter (low-lying coast lines).

(3) It seems that goiter is a disease preeminently of the Great Lakes region and of the extreme northwest.

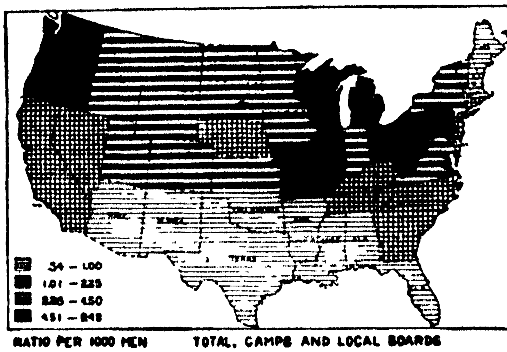
(4) It is almost absent throughout the southern states from the Cape Fear River to the Colorado.

(5) Regions lying near the *tops* of drainage areas show high endemicity (mountain areas, the upper portion of the Mississippi Valley and plateau regions).

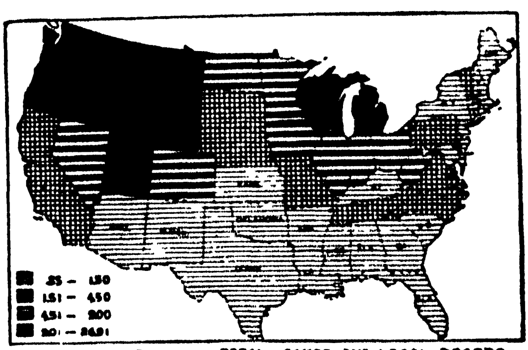
[3] "Defects of drafted men," War Dept. Publication, p. 232.

(6) Regions underlain by the older rock formations show more goiter than those underlain by recently deposited alluvial plains; also regions characterized by thin soils underlain by impervious rocks, both (together with (5) above) connoting thoroughly leached soils.

GOITER, EXOPHTHALMIC



GOITRE, SIMPLE



GOITER MAPS FOR THE UNITED STATES

In considering the goiter maps for the United States, here presented, it should be noted that the endemicities of the two types, simple goiter and exophthalmic goiter, are closely parallel, a coincidence which apparently has hitherto escaped general recognition.

A few specific incidences of certain American localities are reported. Marine and Kimball[4] record that among 2,305 school girls of Akron who were kept under observation for a period of two years, 21 per cent. developed goiter. They mention a maximum incidence of 56 per cent.

[4] "The prevention of simple goiter in man," *J. Am. Med. Assn.*, *77*, 1068 (Oct., 1921).

Clark[5] examined 13,836 school children in 11 counties of West Virginia during the fall of 1913 and found 1,234 cases of goiter (8 9 per cent) ; and 6,432 public school children in 9 Virginia counties and found 817 cases (12 7 per cent.) of goiter. In other states, notably Ohio, Washington, Montana and Vermont, the incidence among school children is estimated by trained observers without an actual census, as varying from 25 per cent. to 50 per cent

The endemicity among domestic animals, where reported, coincides in a general way with that among human beings, in many cases being more marked. When it is recalled that in some of the goitrous regions of the northwest, the mortality from this cause among newborn animals, before preventive measures were introduced, was almost 100 per cent., some idea is conveyed of the prevalence of the disease.

The Thyroid Gland

Some statement of the vital rôle played by the thyroid gland in the processes of the animal body is essential to an appreciation of the subject here treated.

A function of the thyroid is to handle the iodine supply of the body. Its high content of iodine has long been known. This is capable of wide variation, from little or none in cases of iodine starvation, to 0.36 mg. per g. of fresh gland under normal conditions The figure of 0.1 per cent is taken as the lower normal limit, any amount below that indicating iodine deficiency.

The minute quantity of iodine entering the body and assimilated is taken by the gland, it appears, stored up in its colloids and as requirements dictate is readmitted to the circulation as an organic compound.

In the thyroid colloids, it is recognized, is deposited the reserve store of iodine. It is drawn upon, in the opinion of McCarrison, *only when the daily routine of the body demands a greater quantity of iodine than that regularly supplied by the diet.* "The 'emergency ration' of iodine-containing colloid is, however, called upon when the supply of iodine in the food runs short, under the demands of excessive sympathetic excitation, such as occurs in rage or fright (Cannon), at certain periods of life—dentition, puberty, menstruation, pregnancy or lactation—as a result of residence at high altitudes, at certain seasons of the year, and when the body is invaded by micro-organisms or subject to certain intoxications."[6]

[5] Clark and Pierce, "Endemic goiter," Reprint 184, Public Health Reports, U. S. Public Health Service.

[6] McCarrison, "The Thyroid Gland."

"Apparently man's metabolic welfare depends in part on the maintenance of this seemingly insignificant yet actually indispensable store of iodine."[7]

The function of the thyroid gland may best be described in the words of McCarrison,[8] who lists the principal duties of that gland as four in number:

(1) It governs the growth of all cells, and sustains their functional activity. (2) It controls calcium metabolism. (3) It is a profound katabolic stimulant, facilitating the breaking down of exhausted cells and governing the elimination of the waste products of their disintegration. (4) It exercises a protective antitoxic and immunizing action, defending the body not only against the toxic products of its own metabolism, but against invasion by disease producing micro-organisms and injury by their products . . .

The thyroid gland is to the human body what the draught is to the fire; nay, more; its iodine, by its chemical interaction with certain unknown constituents of the cells, is the match which kindles it. . . .

The thyroid gland is specifically associated in the exercise of its functions with the generative organs. . . . By stimulating the development and growth of the sex organs the thyroid secures through them the progress of mental and physical growth; witness their suppression in cretinism and juvenile myxoedema.

Results of Goiter

In discussing the symptomic results of goiter it is conventional to differentiate between the two general phases of the disease, the so-called simple (adolescent or incipient) goiter and the more advanced, exophthalmic (or toxic) goiter or hyper-thyroidism.

Simple goiter, characteristic of adolescence, manifests itself as an enlargement of the thyroid gland, symmetrical swellings near the base of the neck. It attracts little attention. Under superficial diagnosis this may appear as the only recognized result of the disease. However, this should always be taken as a danger signal since as the other extreme there may ensue a failure on the part of the victim to complete the metamorphosis of adolescence. The puerile characteristics may persist, and the lack of physical development may be accompanied by a lack of mental development.

Congenital goiter is perhaps the worst though a less frequent phase of the disease, as it foredooms the child to a subnormal existence. As a first effect it increases the mortality among newborn infants. If the infants survive they are the victims of physical and mental degeneration, with bodily deformity and mental imbecility, and frequently mutism, deaf-mutism and idiocy—cretinism. Goiter in the mother is the cause of goiter in the unborn child.

Exophthalmic goiter, more common among adults, while frequently accompanied by an enlargement of the thyroid gland, mani-

[7] Ed. *J. Am. Med. Assn.*, *77*, 1574 (1921).

[8] *Loc. cit.*, p. 22.

fests itself rather by a serious derangement of the nervous system, with rapid pulse, especially on excitement, and tremor. It causes a greatly depressed state of health, with loss of flesh, and a general derangement of the functional activities of the body. Protruding eyes (exophthalmos) is a symptom of an advanced stage, and insanity and death may be its culmination.

Or, myxedema may ensue, in which case there is a thickening of the skin and enlargement and coarsening of the features, with dropsical symptoms, a loss of memory and general mental degeneration

"There are few human beings living under modern conditions of life in whom the [thyroid] gland is wholly normal."[9]

In domestic animals—whose diets may also be arranged in accordance with man's ideas as to what constitutes a proper ration—goiter leads to a high rate of mortality among the newborn, where it exhibits itself as "big neck" among calves, "weakness" in foals ("weak colts"), "hairlessness" among pigs, "weakness" among lambs and "big neck" or "hairlessness" among newborn goats.[10] It also occurs among dogs, cats and chickens.

Cause of Goiter

"The immediate cause [of goiter] is a lack of iodine "[11] Since the presence of certain amounts of iodine in the diet almost invariably prevents its occurrence and in the majority of cases in the early stages of the disease causes its disappearance, as attested by abundant experimental data, this conclusion is substantiated. It is one of the simplest and most thoroughly authenticated instances of a deficiency disease.

Marine[12] found that young fish in a hatchery in Pennsylvania were being exterminated by goiter and promptly eradicated the disease by adding iodine to the water in which they were being maintained.

Halstead showed that if the thyroid of a dog were partly removed the remaining portion would begin to enlarge, and Marine[13] showed that if iodine were administered to the dog under those circumstances the remaining portion of the thyroid would not enlarge. Marine and Lenhart[14] demonstrated that goiter developed in dogs if they were deprived of all iodine, as soon as the iodine content of

[9] McCarrison, *loc. cit.*

[10] Kalkus, "A study of goiter and associated conditions in domestic animals," Bul. 156, Ag. Expt. Sta., State College of Washington.

[11] Marine and Kimball, *loc. cit.*

[12] Bul. 7, Penn. State Fisheries.

[13] *J. Inf. Dis.*, IV, p. 425 (1907).

[14] Arch. Int. Med. *3*, 66 (1909).

the gland, through exhaustion, fell below a certain limiting percentage and conversely that goiter could not be induced where iodine was supplied. Finally, Marine and Kimball[15] in 1917 in their classic demonstration with the school children of Akron, Ohio, showed that the facts established with animals applied in general quite as well to human beings, the most spectacular and fundamental piece of work that has been done in America in connection with this deficiency disease and ranking in importance with the other great basic demonstrations in disease prevention.

Goiter has been ascribed circumstantially by various writers to various causes, many conflicting and contradictory, which can be compromised only on the basis that any set of circumstances which entails extraordinary demands on the thyroid gland will, *when coupled with a deficiency of iodine,* tend to induce goiter. In all the mass of evidence bearing on the subject there seems to be nothing which successfully controverts the statement of Marine and Kimball that if the iodine store in the thyroid be maintained above 0.1 per cent. no hyperplastic changes and therefore no goiter can develop.[16] The cause of goiter seemingly is demonstrated beyond a peradventure.

Iodine as a Preventive and Cure

Dr. Richard Russell in 1752[17] described the use of sea water in the treatment of goiter. The Swiss have long known that an occasional sojourn at the seashore would result in practical immunity, an expedient restricted to the well-to-do. Since the work of Coindet (1820) the value of iodine in the treatment of goiter has been on record. The eradication of goiter among fish by administering iodine has been demonstrated by Marine[18] in 1910, and Gaylord and Marsh[19] in 1914; among animals by Marine and Lenhart,[20] Smith,[21] Hart and Steenbock,[22] Welch[23] and Kalkus.[24]

In America the first large-scale application of preventive and curative measures to human beings was the demonstration by Marine and Kimball with the school children of Akron in 1917,[25]

[15] *Loc. cit.*

[16] "The prevention of simple goiter in man," *loc. cit.*

[17] "The Use of Sea Water in the Treatment of Glandular Diseases."

[18] Bul. 7, Dept. Fisheries, State of Penn.

[19] Bul. 32, U. S. Bureau of Fisheries.

[20] *Loc. cit.; cf.* also *J. Exp. Med., 19,* 70 (1914).

[21] *J. Biol. Chem., 29,* 215 (1920).

[22] Bul. 297, Agr. Exp. Sta. Univ. of Wis.

[23] Bul. 119, Ag. Exp. Sta. Univ. of Montana, "Hairlessness and goiter in newborn domestic animals."

[24] Bul. 156, State Col. of Wy., Ag. Exp. Sta., "A study of goiter and associated conditions in domestic animals" (1920).

[25] "The prevention of simple goiter in man," *loc. cit.*

referred to above, in which some 4,500 children were placed under observation. These were divided into two groups: to the first, 2,190 in number, iodine was administered, of which number only 5 developed goiter, while among the second group, 2,305 in number, who did not take the treatment, 495 developed goiter (0.2 per cent *vs* 21 per cent)—a demonstration of the preventive efficacy of iodine of the most convincing sort. Furthermore, as to the curative power of iodine, it was shown that of 1,182 pupils with thyroid enlargements at the beginning, 773 (65 per cent.) showed a reduction as a result of the treatment.

Klinger (1921), in experimentation with the school children of Zurich, where the incidence was 82–95 per cent, showed curative effects in 73 per cent of cases after 15 months' treatment.

The Distribution of Iodine

Iodine existing on the earth in forms that are mostly highly soluble in water, the bulk of it is to be found in the sea whither it has been deposited by drainage water and when it exists in a concentration of less than 0 01 gm per liter. In the rocks which have had their origins in the sea, some traces of iodine remain and in the drainage waters flowing over and through them. This small trace diminishes in concentration as the tops of drainage areas are approached, there the soils being more thoroughly leached out The same is true of thin strata of soils overlying impermeable rocks. In this connection attention is called to the remarkable results obtained by McClendon in his study of the iodine content of potable waters as related to goiter incidence.[26] Higher concentrations are found in soils and drainage waters occurring nearer the ocean, although here undoubtedly drainage is only one factor, as the supply of iodine is increased by sea spray blown inland.

Small and varying amounts of iodine may be found in plants and in the animals feeding upon them. The occurrence of iodine in food materials with relation to goiter has been studied by Forbes and Beegle.[27] While they find that there is not a sufficient divergence in iodine content of the foods grown in goitrous and non-goitrous regions to account for the varying incidence of that disease, they point out "the smallness of the proportion of our food products which contain iodine, the minute quantities in which iodine is ordinarily found and the haphazard nature of its distribution."

[26] "Simple goiter as a result of iodine deficiency," *J. A. M. A.*, *80*, 600 (1923).

[27] Bul. 299, Ohio Ag. Expt. Sta.

Just as the soils occurring near the ocean contain more iodine, so it is to be expected that the plants growing thereon will likewise, and it is shown by Hunter and Simpson, as stated by McCarrison, that the thyroids of sheep grazing near the ocean contain more iodine than those grazing inland.

But the occurrence of iodine to a remarkable degree in plants is confined to those that grow in the sea. In certain seaplants the iodine content, as will be shown, is phenomenal.

The foregoing suffices to show the intimate manner in which the normal supply of iodine for the metabolic use of the human body is linked with the sea. And in this connection it may be suggested that in this fact is found a biochemical bit of evidence in support of the theory of evolution, or at least that part which hypothesizes a marine origin of animal life. Our early metabolism being established on the basis of chemical elements always present in that medium of existence, it has not been possible yet to evolve a new system of life chemistry which can do without them. McClendon[28] voices the same idea in a different manner when he says:

> It has been considered by some biologists and chemists that living matter originated in the sea and the elements of living matter correspond to those found in the sea water. We might look, therefore, to the composition of sea water for the elements we should expect to find in living matter.

Entirely in support of this evident close relationship between goiter and the sea are the goiter maps here presented. The data on which they are based show that the incidence of simple goiter varies from 1 02 among men residing near the sea to 17.55 among those from inland regions. They illustrate the increasing incidence as tops of drainage areas, the Appalachians, the Great Lakes Regions and the Rocky Mountain Regions, particularly the Pacific Northwest, are approached. When multiplied by six they may serve to show the order of incidence among women.

It will be noted, by a comparison of the respective maps for "simple" and exophthalmic goiter, that there is a remarkable parallelism between the proportional incidences of the two forms. Both are derangements of the thyroid gland and both involve a deficiency of iodine in the gland. They occur side by side, the general conditions that induce one—so far as those conditions are understood—inducing the other. Both are the result of hyperactivity. In one the hyperactivity takes the form of hyperplasia, while in the other, of excessive secretion. Both respond to iodine treatment. Are they not obviously different manifestations of the same thing? One is demonstrably the result of iodine deficiency. There is no conclusion but that the other is also.

[28] "Are iodides food?" *Science, 55,* 1423 (April 7, 1922).

Lack of Iodine in Normal Diet

The modern diet is made up largely of highly refined materials, seeds constituting most of it. These, in their natural state, in addition to materials of great value as sources of energy, contain many of the mineral elements and compounds essential to animal life and growth. But in most cases they are refined to the point where the latter are eliminated As a result when used alone they are not able to sustain life, it has been shown that animals fed on certain of them exclusively perish more quickly than do those entirely without food. The excessive use of refined foods leads to deficiency diseases Over-refinement in food manufacture deprives us of essential elements which under less artificial conditions would be a natural part of our diet No automatic method is provided for supplying these materials, of great importance in every case, but of the greatest importance in feeding the young. The diseases of the bones in growing children as a result of deficiencies are well recognized. Less attention is paid to the frailty and inadequacy of the teeth as a result probably of similar causes.

Together with deficiencies of the many commoner elements, there occurs, of course, an even more marked deficiency of iodine. The slight occurrence of iodine in food materials is shown by the elaborate research of Forbes and Beegle as illustrated by the following summary.

The various groups of food materials analyzed, in the order of the increasing frequency of iodine occurrence, are as follows: (1) Nuts; (2) spices, condiments and stimulants, (3) fruits; (4) cereals; (5) hogs, silage and forage crops; (6) garden vegetables and root crops; (7) leguminous seeds; (8) animal products, and (9) manufactured foods and milling and manufacturing by-products. "Among the cereals iodine was found as an uncommon constituent, usually in traces only."

Method of Supplying Iodine to the Diet

As a source of iodine for human metabolism it is obvious one must look to the sea, the great storehouse of that essential element, and choose that method of securing the requisite quantity in the manner which most readily coincides with one's already established dietary habits. Sea foods might well become a more common article of diet, but at the present cost for preservation and transportation do not reach the majority of people. Sea salt is not a commodity at present cheaply obtainable; its wide introduction as a condiment would be of great benefit to the human race. A logical and from many points of view an ideal conveyor of all these essential elements are the kelps, the larger sea weeds of the brown algae group.

Composition of Kelp

Chemical literature is replete with references to investigations of the composition of kelp. They have been studied from the point of view of their utilization as foods, and as carriers of inorganic salts and iodine.[29] The different species vary in chemical composition, quantitatively rather than qualitatively. Most of the work in America has been devoted to the giant kelp of the Pacific, *Macrocystis pyrifera,* made the basis of the extensive investigations of the U. S. Department of Agriculture. Its composition is more thoroughly understood perhaps than that of any other sea plant.

The composition of this kelp has been studied to determine its water, organic, inorganic, nitrogen, protein, sugar and fat content. It is tremendously complex, being made up of a great variety of organic and inorganic compounds and of organic compounds containing and combined with mineral elements. In organic combination are parts at least of the iodine, the phosphorus and the sulfur. In the plant, all of them are held in varying degree in colloidal suspension.

The many analyses of *Macrocystis pyrifera,* made in state and federal laboratories, show on the average: Potassium chloride 22 per cent., sodium chloride 10 per cent. and water-insoluble ingredients 7 per cent. (on the dry basis). Entering into this total of 37 per cent. inorganic material are: Calcium, 4.96 per cent.; magnesium, 2.24 per cent.; sodium, 10.52 per cent.; potassium, 29.46 per cent.; iron and aluminum oxides, 0.43 per cent.; chlorine, 34.93 per cent ; sulfur (calculated to SO_3), 7.92 per cent.; CO_3, 4.44 per cent.; phosphorus (calculated to PO_4), 2.30 per cent.

While all the kelps contain iodine, the iodine content of this species is phenomenal. Of 29 samples analyzed for that element, an average content of 0 26 per cent. was shown, with a maximum of 0.41 per cent. and a minimum of 0.17 per cent.

From the foregoing it is evident that this kelp contains the principal ingredients of sea water, and has stored them up within itself in even greater concentration than most of them exist in sea water. This is particularly true of potassium and iodine. It appears, therefore, to be an ideal concentration of the desirable elements of sea water with the relatively marked elimination of the most common and least valuable—common salt.

Adaptability of Kelp as a Diet Amendment

As a conveyor to the diet of the essential mineral elements, kelp possesses many ideal characteristics. It is a carrier of iodine of remarkable properties—a high content of iodine together with a great assortment of other useful elements. The source of raw material

[29] Turrentine, "Potash from kelp" (I–VIII), *J. Ind. and Eng. Chem.,* Vol. *11,* (1919), to Vol. *16* (1924).

is abundant. Methods have now been perfected whereby it may be so processed that its colloidal constituents remain unimpaired and its mineral content unreduced. When so processed it is a carrier of these elements and compounds in a natural, vegetable colloidal suspension, from which or through which they may be taken up by slow, digestive processes just as they would be if they were made available as natural constituents of usual articles of diet. Being highly concentrated in these, preparations may be made in condensed forms so that the convenience wherewith they may be added to the diet is greatly enhanced For the latter purpose they may take a variety of forms, suitable for addition to the diets of people of varying ages and dietary habits. It is important that kelp to be used for the control of goiter be employed as a preventive as well as a cure, particularly that it be added to the diet of the young and to all those approaching or experiencing life crises. It is contended by some that its addition to the diet should be made a part of a culinary or dietary routine and not left to chance or the caprices of the memory. On the other hand, the disciplinary and educative advantage to be had from consciously taking as a diet amendment a concentrate of essential elements must not be overlooked. Being abundant, cheap and conveniently acquired, transported and stored, it should be made available for all peoples of all lands. Through its instrumentality, as a carrier of iodine and other desirable elements, not only goiter but other diseases depending on related deficiencies may be eradicated.

The present methods of combating goiter by the administration of metallic iodides or thyroxin leave much to be desired. The administering of iodides, as, for example, dissolved in the drinking water of a school, results in uneven dosage, though rarely in such an excess dosage as to cause symptoms of iodine poisoning; yet Bircher[30] describes the practice as causing harm and is supported by others in this contention.

What the situation requires is iodine in a form as closely as possible approximating the natural form in which that element is normally taken into the body, in organic combination, preferably as a constituent of food materials Salts of iodine radically fail to meet this requirement. Those employed are very soluble and therefore are able to overcome the natural metabolic balance of the body solutions and thus rapidly to force their way into the circulation and out. The situation calls for a food, not a drug.

With a natural food material at hand, the wisdom of resorting to drugs for feeding is open to question. It must be remembered that iodine is administered in goiter not on account of any physiological action it may have as such. On the contrary, its physiolog-

[30] Schweiz, Med. Waschr., *52*, 713 (22).

ical action—as exhibited by iodism, for example—is exactly what one desires to avoid. It is given merely to furnish raw material to the thyroid wherewith to manufacture essential secretions. The situation demands physiologically inactive iodine, insofar as such is attainable.

Soluble iodine is not necessarily assimilable iodine. And in this connection it may be remarked that while the interconnection between iodine and goiter has been known for a hundred years no appreciable impression on the progress of the disease has been accomplished by the use of iodides. On the contrary, it appears that goiter is on the increase, a fact attributable to the increased use of refined foods and of surface water for drinking purposes and demands for nervous energy occasioned by our modern social régime.

Curative Powers of Kelp

This suggested use of kelp, based on *a priori* considerations, has within recent months been subjected to a rigid clinical demonstration with results so uniformly favorable as to exceed expectation. Under the supervision of skilled endocrinologists victims of goiter of a variety of involvements have been treated with standardized kelp extracts and with very few, if any, exceptions have responded favorably. Under this treatment heart action and metabolism have been restored to normal, the swelling of the thyroid glands reduced, nervous disorders have disappeared and in every case where frequent periods of violent insanity formerly occurred—requiring the confinement of the patient in an institution—these have entirely ceased to appear.

The Eradication of Goiter

The importance of maintaining the proper functional activity of a gland as vital to our physical well-being as is the thyroid can not be overestimated. The ease with which that may be done makes its neglect inexcusable.

The time has now arrived when goiter must be eradicated. Our knowledge of the cause of the disease, its prevention and cure has reached the stage where we can proceed with confidence to that end. Those responsible to the public for the state of the public health, those interested in the betterment of public health are now in a position where, with cooperation, through moderate educational propaganda, they can persuade the public to take for itself the simple step which will insure an adequate iodine supply in the diet to prevent the development of goiter, to arrest the course of the disease where developed, and in the majority of cases to effect cures. By concerted action within a brief period this dread disease may be eradicated—and further honors thus be made to accrue to those who are devoting their lives to disease eradication through preventive medicine.

SOME COMMON BUT LITTLE KNOWN CAVE DWELLERS

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In the dark recesses of a cavern like the Mammoth Cave of Kentucky there may be found thin-skinned, white, blind creatures of different kinds, and we call these cave animals.

All surface soil has somewhat similar but infinitely smaller crevices and crannies distributed through it. In these spaces are found innumerable animals. Some of these are surface animals which use the crevices for permanent homes or merely for temporary hiding places. Such animals are in the soil only incidentally. The squirrels which live in holes in trees in the eastern United States are represented in California by burrowing forms. These "ground" squirrels, however, obtain their food from the surface as the eastern squirrels do and use burrows as the most easily obtainable homes.

The prevention of evaporation from the surface of the body is one of the important problems for land animals. A thick, impervious covering of armor plate such as covers lizards, insects or pill bugs, or an oily, flexible, hair-covered skin like the mammals have is an effective moisture conserver.

Animals of this sort, though they may live underground, are pigmented normally and spend much time on the surface in the light. Most species of ants are examples.

There are, however, a number of animals, white and blind, which live permanently in the semi-microscopic chambers in the soil and are visible only by accident. Among these forms are included a few of the smaller worms, a number of the more delicate wingless insects, tassel tails and spring tails, and two of the orders of that artificial group of animals, the Myriapods.

These are all small animals, able to make their way between the superposed leaves on the forest floor or the particles of soil in it and find their food in such constricted spaces. They never of their own choice come to the light nor are they found where the atmosphere is far from the saturation point. In the soil they live and breed, migrating upward or downward as the combination of heat, light, food and water supply determines the optimum living conditions.

In order to show the relationship of the Myriapods to be discussed it will be desirable to give a brief history of the class.

In the twelfth edition of the "Systemae Naturae" in 1766, Linnaeus included the Myriapods with insects and named a number of species of both centipedes and millepedes. Since classifying had not yet arrived at a settled system the writers who followed Linnaeus shifted the Myriapods according to their pleasure, classing them with spiders, with scorpions and even with serpents. Early in the nineteenth century Leach took the name proposed by Latreille and constituted as a separate class the Myriapoda or thousand legs.

In 1887–88 Pocock and Kingsley, studying the Myriapods from the standpoint of relationship, each came independently to the conclusion that the group was not a natural one, because the possession of a larger number of legs than three or four pairs was not a sufficient basis for grouping. They recommended that the Myriapods should be split into two unequal groups, the one to contain the diplopods or millepedes, the symphyla and the pauropods and the other to include the chilopods or centipedes. This latter group is quite closely related to the insects, many of which have more than three pairs of legs either as embryos or adults.

This is the accepted classification to-day, though we may and probably will retain the name Myriapoda as a convenient if unscientific name for four very different types of jointed-legged animals.

The arguments for this separation of the Myriapods into two sections are numerous and convincing.

The most fundamental is that in the millepedes, symphylans and pauropods the reproductive organs open on the ventral side of one of the anterior body segments (2–4), whereas the centipedes, as the insects, have the sex opening at the posterior end of the body.

The centipedes all possess anterior legs transmuted into poison fangs, while the millepedes have no such organs. Many millepedes are provided with repugnatorial glands along the sides of the body which secrete an unpleasant protective material like hydrocyanic acid.

In general the centipedes are carnivorous and the millepedes herbivorous.

The Symphyla and Pauropoda are the least known of the myriapod orders because of their small size and their light-shy habit of life. They are, however, not uncommon where the conditions of heat and moisture are satisfactory, and the Symphyla especially have been long known.

In 1763, Scopoli saw and described one of these small animals, naming it as of the centipede genus Scolopendra and its species nivea or white.

In 1836 Gervais discovered a similar creature which he took for a larval Geophilid and called Geophilus junior. But on counting the antennal joints he found that it had more than any adult Geophilid possesses, so he named the animal Scolopendrella, the diminutive of Scolopendra, the centipede.

Because of its habitat in the soil he maintained the genus among the Geophilidae. Newport, the English myriapodist, however, removed Scolopendrella from the Geophilidae and placed it as the Scolopendrellidae, a family of equal rank, between the two carnivorous forms of centipedes, the Lithobüdae and the Scolopendridae.

To quote from Latzel, "these harmless things must have been not a little worried at being set down between such outspoken robbers and it was high time a savior should appear for them. This savior has lately appeared in the person of the American naturalist, J. A. Ryder, who has taken the poor creatures out of their unnatural environment and has made them the type of a separate Arthropod order, the Symphyla or connecting link."

Ryder's idea was that since Scolopendrella presents so many characters which also appear in the lowest insects, it must represent a connecting form between insects and myriapods. Time, however, has not dealt gently with this conception, and the Symphyla, instead of being considered the simplest myriapods and closely related to the primitive insects, now appear to be among the most specialized of their race and a terminal branch of their particular line.

The Pauropods

The Pauropoda were so named by Lubbock in 1866 because they have but nine pairs of legs, the least number found in any adult myriapod. The first species was dedicated to Professor Huxley. There are now three genera and a number of species known.

The order falls into two parts, the slow moving and the agile pauropods. By analogy with millepedes and centipedes, the slow moving pauropods should be herbivorous and the rapid ones carnivorous.

They range from one half mm to one and one half mm in length, the largest then being somewhere near one eighteenth of an inch long.

The pauropods have antennae which end in three flagellae. They are very different from the antennae of any of the other higher arthropods and suggest the branched antennae found in crustacea. These peculiar antennae make identification of the order very easy since in order to serve as eyes, ears and possibly nose for the animal they project notably from the sides of the head and from beneath the protecting armor when there is any.

The agile Pauropus is an ideal cranny and crevice dweller. Its body is much compressed from side to side and is set up high on the legs. The hinder legs are longer than the more anterior legs and it runs rapidly. It is able to make its way into the cracks in drying wood or similar spaces.

The slow moving Eurypauropus has a body compressed dorso-ventrally, covered with chitinous scale like armor, sculptured and variously ornamented. In this case the legs extend out laterally but do not project beyond the armor and the animal is adapted for creeping under the loosened bark of dead trees.

These animals are exceptional in that their small size permits them to oxygenate their tissues without any specific respiratory system such as the tracheae of millepedes. It has been suggested that the animal's fat body may have a respiratory function. The delicacy of the chitinous envelope and the size of the animal is such that each body cell is able to carry on respiration for itself.

As an accompaniment to this there is no circulatory system at all, since the physiological processes go on in such a small space that the body cells can obtain the food dissolved by the wall of the digestive cavity.

The cells of Pauropus eliminate their waste products (in the reverse direction of the oxygen intake) through the outside of the body, but the heavier bodied Eurypauropus has two intestinal diverticula or Malpighian tubules, as the millepedes and insects have, for excretory organs.

The young leave the egg with three pairs of legs, as do the regular millepedes. This hexapod condition was at one time very much stressed as indicating close relationship with the six-legged insects, but whatever significance it has must be that of parallelism, since the differences between millepedes and insects given earlier are fundamental.

Because of the exceeding small size of these pauropods little has been learned of the life history. When this shall have been learned for the two lines they may turn out to be more closely related to the regular millepedes than is now supposed.

The Symphyla

The Symphyla range from a maximum of eight mm in length downward. They are, therefore, notably larger than the Pauropods, but are still very small compared to the most of the myriapods.

There appear to be about 15 segments after the head. They are eyeless, with wonderfully sensitive antennae which look like little strings of pearls and can be elongated or shortened at the need of the animal.

They run quite actively, standing high on their legs and thus give the impression of small white centipedes. They can move backwards as well as forward. In the ground they often, if not always, spin a delicate thread of web from the cerci at the hinder end of the body as they travel and so they can retrace their path if it is necessary by following the web. They will always spin such a thread if they are carefully lifted from the substratum and then given the opportunity to drop.

When disturbed, they are likely to feign death, lying quiet with the body in the shape of a crescent. If then the animal be treated roughly the antennae will move hastily for information and the animal will wake up and hurry away.

There are at present two genera known in the order. The number of legs and the shape of the tergite or dorsal shield of the body segments determine to which of the two genera, Scolopendrella or Scutigerella, the individual belongs. Scutigerella as an adult has twelve pairs of legs with one pair of jointed appendages or parapods, near the origins of the last ten pairs. The tergites, of which there are 15 in number, have their posterior corners rounded and the last one is concave posteriorly. The tergites in Scolopendrella, on the other hand, have the posterior corners extended backward as sharp points and the hinder boundary of the last one is at right angles to the axis of the animal. Scolopendrella appears to have eleven pairs of legs, since the first pair of Scutigerella either does not appear at all or appears as rudimentary stumps.

The breeding season in Ohio comes in May and June. There is no evident difference between the sexes unless it be that the males are smaller than the ripe females.

In an enlargement in the runway the female deposits from three to eight eggs and bends herself about them, probably for the sake of keeping off fungous growth. The eggs are most beautiful objects, spheres, about a millimeter in diameter, pearly white with a geometrical pattern of ridges over the surface which reflect the light.

The American species fasten the eggs together in a ball with web, but a species reported from Malaysia spins a short stalk and sets the mass of eggs up on this stalk, thereby gaining a greater immunity from fungus or from the attacks of the semi-microscopical parasitic mites which rather commonly infest the adults.

The time of hatching is dependent upon the temperature. In one case where the eggs were laid in a space under a glass slide and kept under daily observation the time was ten days.

The larvae escape from the egg with either six pairs of legs (Scolopendrella) or seven pairs (Scutigerella) and add the rest of the legs in a series of moults.

The symphyla are reported to breathe by means of a pair of spiracles with attached tracheae which open on the head of the animal. If this is correct it is the only case known in the arthropod phylum. Without any doubt there is a series of eversible sacs found along the ventral side of the animal near the bases of the legs. Similar structures are found in Thysanura among the insects. It is suggested that these are respiratory organs. The method of oxygenation of the tissues through the delicate chitinous surface is probably the principal one.

There is a heart present, similar to the circulatory organ in larger animals of the arthropod type.

Excretion is carried on by means of Malpighian tubules.

The alimentary canal is essentially a straight tube. The question of what they eat is not definitely settled. The agility and rapidity of movement and the fact that the mouth parts grasp forward, as in the centipedes, instead of downward, as in the millepedes, together with the simplicity of the alimentary system, would indicate a carnivorous habit. There are numerous microscopic protozoa and arthropods in humus such as the symphylans frequent. The fragments of wood which are found in sections of the digestive cavity could be taken accidentally along with the animal food or of course might be the less digestible part of a vegetable diet.

General Considerations

Neither the pauropods nor the symphylans can survive steady trampling or cultivation of the soil they inhabit. They are therefore more likely to be found in undisturbed forests or the parts of pastures too rough to be tramped down by animals, or along the bottoms and sides of gullies where the stones are large enough not to be moved by common freshets.

When the leaves fall in the autumn, the ground is moist and the relative humidity of the air approaches 100 per cent., then both pauropods and symphylans may be found above the surface of the ground in the narrow spaces between the packed fallen leaves.

As long as decaying wood is moist it is also a favorable habitat, as it furnishes crevices small enough to protect from marauding animals. I have found Scutigerella breeding in wood in preference to soil, while Scolopendrella seems to prefer the soil.

When everything is dry in the late summer these animals go down in the soil or under heavy stones until they reach the favorable conditions of moisture and coolness.

Even in favorable situations they are likely to be found scattered in discontinuous groups rather than distributed uniformly throughout the soil. The type of habitat, the crevices in humus, can not

have changed much in the history of the world, and after these minute creatures were adapted to this habitat one would not expect them to change much either.

The two groups offer the same evidence for geographical distribution. Both pauropods and symphylans are found in both Europe and North America, the same genera and in some cases the same species. This fact demands a continuous land connection between Europe and America at a time after the differentiation of these two orders from the ancestral progoneate millepede-like stock.

In North America all life was destroyed during the glacial period as far south as the icecap reached. The organisms have migrated back again over the area left by the withdrawal of the glaciers.

The islands of Lake Erie have been separated from the mainland ever since the disappearance of the ice by the waters of the lake now called Lake Erie, which in the past was a much larger body of water than at present.

Wingless animals which can not swim have had to be taken to the islands by some transporting agency. Creatures like the pauropoda and symphyla, which are so small that it is not likely that any larger animal would carry them, either by intent or accident, would have to depend for their dispersion on floating wood. This is probably the means by which all the millepedes, spiders and such forms reached the islands, since they are very likely to conceal themselves in the crevices of decaying wood.

Scutigera, the house centipede, does not live in wood but in the crevices between stones. Although there are favorable stone habitats on most of the islands and although Scutigera has been found on Marblehead peninsula only a few miles away, it has not been found on the islands. We may conclude, then, that all myriapods found on the islands of Lake Erie have reached there by the driftwood route within the last ten thousand years or whatever time it has been since the last withdrawal of the ice from Ohio.

The Symphyla and Pauropoda will never be of any significance to the average man because of their small size, their limited numbers and their lack of economic importance. They are wonderfully well adapted to the underground environment, however, and will probably persist as long as there are favorable undisurbed situations where they can find their minutes caves in which to dwell.

BOTANIZING IN PERU

By Dr. A. S. HITCHCOCK

U. S. DEPARTMENT OF AGRICULTURE

ON October 11 I left Guayaquil for Callao the port of Lima. The prospective traveler to Ecuador should know that it costs something to get out of that country as well as to get in. I was obliged to get a permit to leave, costing sucres 20.80, before the steamship company would sell me a ticket.

As the steamer stopped for a few hours at Paita, I landed to look things over. Although only a short distance from the southern border of Ecuador the country was a desert. No living thing could be seen on the hills around the town. This was the beginning of the great desert extending from northern Peru into northern Chile. Throughout this region the population is found in the isolated valleys of streams that flow from the Andes to the ocean, their waters providing irrigation for agricultural industry of the coastal plain. The most important crops are sugar and cotton. The isolated communities of these valleys depend upon steamer service for their communication with the outside world as there is no railroad paralleling the coast.

The sea was calm, as it usually is along the Pacific coast of South America, the sky was bright and the weather cool, so cool in fact that I had to wear a sweater. At Salaverry I saw a wonderful sight. The steamer was anchored off shore and just outside was a constant stream of birds flying northward, hour after hour, countless thousands, within a few feet of the surface, as far as the eye could reach in either direction.

As the steamer did not come to a dock at Callao there was the usual confusion in getting ashore by launch. Fortunately there is a tariff for charges. There is a blanket charge from the steamer to the hotel at Lima. This includes launch to Custom House, through the Custom House to train for Lima (about a half hour inland), and from train to hotel (2 trunks at 5 soles each, and 4 bags at 2.50 soles each, 1 sol for myself and hand baggage). The Custom House officials were very courteous, passing my baggage without opening it. After getting letters for use in the interior I started for Oroya and Cerro de Pasco, lying in the sierra over the western range of the Cordillera. The railroad is a wonderful piece of engineering. We first traverse the coastal plain and begin to climb about 10 o'clock. Then we do some of the most spectacular

climbing I have ever seen. At 3 o'clock in the afternoon we go through a tunnel (3,757 feet long) at the summit of the pass at an elevation of almost 16,000 feet. There is a severe strain on the human organism in going to such an altitude in so short a time and many suffer from soroche or mountain sickness It was fortunate that I was not affected by altitude as I was in the sierra for about ten weeks The construction difficulties may be estimated from the fact that on the road including the branch to Huancayo there are 65 tunnels, 10 of them more than 500 feet, 21 switchbacks, and 61 bridges.

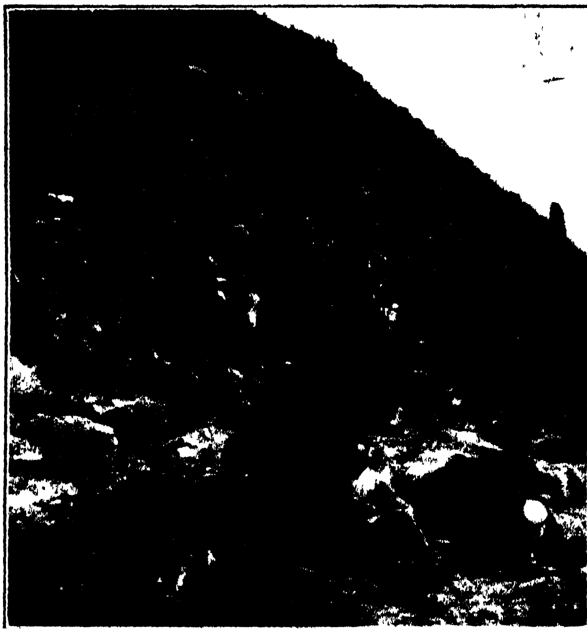
At Oroya (12,000 feet) is the big smelter for the Cerro de Pasco copper mines Fortunately I had the privilege of stopping at the company's hotel which was very comfortable. The rooms were heated with electric stoves and the meals were American style. Mr Colley, the manager of the smelter, kindly made arrangements for a trip to Colonia Perené, a plantation in a valley to the east. An autobus took me over a high páramo or puna to Tarma, and another down a long slope of about 10,000 feet to La Merced. The road on this slope was good but so narrow that autos cannot pass and the traffic goes up one day and down the next The descent was made in the rain, after dark, at a terrific speed, a precipice on one side and a drop-off on the other, around sharp curves, the driver half Chinese and half Indian—altogether a hair-raising ride. My anxiety was increased by watching the speedometer as it hovered between 30 and 35 miles an hour. On the return trip I discovered that the speedometer recorded kilometers instead of miles (1 km = 0 6 miles) The following day I went mule-back to Colonia Perené where my letter brought a warm welcome from the manager, Sr. Valle-Riestre. The plantation is devoted mostly to coffee of which there are 1,600,000 trees. As the altitude is 2,000 feet the flora was tropical.

The next stop was at the Atocsaico Ranch about 12 miles west of Junín. This ranch is chiefly devoted to sheep. During the ride from the station to the ranch we passed through a hard sleet storm. At the ranch I was looked after most hospitably by the manager, Mr. McKenzie (and his assistants McLeod and McLean—none of them Frenchmen), and Sr. Rizo-Patron, son of the owner of the ranch. My! How I did enjoy the oatmeal and cream—real cream, something I had not seen since I left the states. Here, at 13,000 feet the grazing is excellent all the year, plenty of grass, plenty of water, ideal for sheep At this altitude there are no trees and fuel is expensive. At the little stove in the ranch house dried turf was burned. Sheep manure is also used. There is a dynamo and soon the power, light and heat at the ranch will be electrically

PLAZA AT AREQUIPA
Mt Misti (19,200 feet) in background

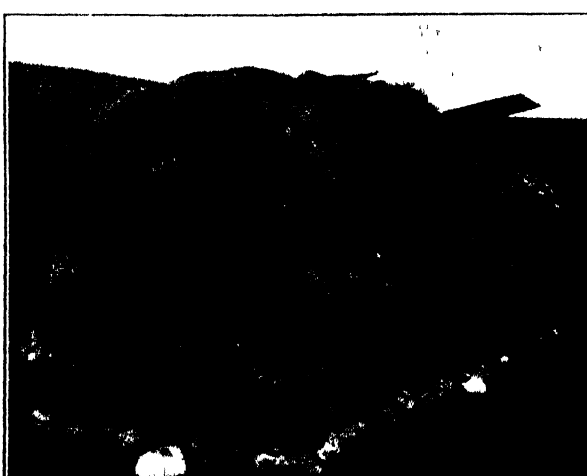
supplied by water power Those who have not visited these high altitudes can scarcely appreciate that even in the tropics the climate is cold and bleak. Although well prepared I was constantly fighting the cold I had a good bed at the ranch but there was no heat.

STONE HUT, ATOCSAICO RANCH, 13,000 FEET



CACTUS NEAR AREQUIPA
Sr Delgado Vivanco in center.

There were eight blankets on the bed and Mr. McKenzie had thoughtfully provided a hot water bottle for my feet. With all this I was cold and finally got up and put on wool underwear, still later I put on a wool shirt—only then was I warm Sitting during



DRYING TURF TO BE USED FOR FUEL
Atocsaico Ranch, central Peru, 13,000 feet.

the evening in a chilly room increases the sensitiveness to the cold after retiring. On the ranch (11,000 acres) there are about 35,000 sheep and the annual production of wool is about 60 tons. In one of the barns was an immense pile of condor wings upon which a bonus had been paid Condors are a great pest here as they destroy the sheep

After three pleasant days at the Atocsaico Ranch I went on to Cerro de Pasco, the seat of the great copper mine, where I had the privilege of stopping at the company hotel. Cerro de Pasco is a cold bleak place at 14,300 feet altitude and I appreciated the steam heat at the hotel The railroad from Oroya to Cerro de Pasco passes

WOOLLY CACTUS (*Opuntia floccosa*)
Atocsaico Ranch, 13,000 feet. Fountain pen in center.

over a great high plain 13,000 to 14,000 feet elevation, with mountain ranges still higher in the distance.

The hills around here are covered with a curious tussock grass called moss-grass (*Aciachne pulvinata*) of no use for forage. The bunches are hard, with a covering of short spiny leaves. As the bunches increase in size they die in the center, thus forming fairy rings.

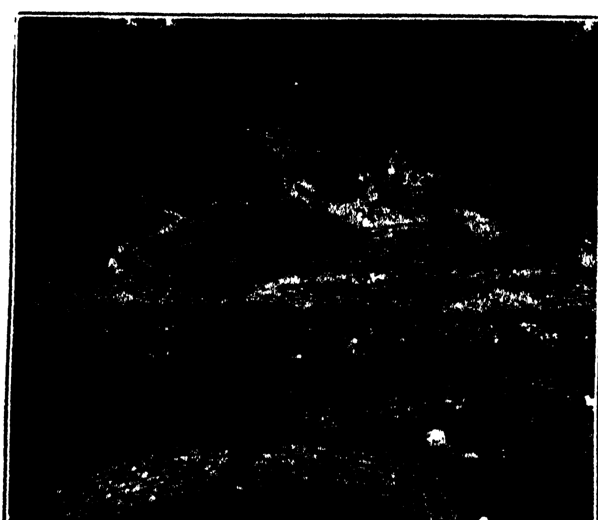
Mr. Philpott, the manager of the mines, interested himself in my work and made arrangements for a trip to La Quinhua, a gold mine, down one of the valleys, and to the company's coal mine at Goyllarisquisca (it took me a long time to understand this word). I remember the trip to La Quinhua because I got so cold coming

TERRACED FIELDS, AREQUIPA
Crops are grown under irrigation in all the valley and well up on many of the slopes

back I had on heavy cotton underwear, an army wool shirt, a heavy wool sleeveless sweater, a vest, a wool-lined leather vest, a coat, a heavy waterproof poncho, seven thicknesses, yet on my arrival at the hotel that night in a cold rain I was suffering greatly from the cold—and it was in the tropics, 11° south latitude.

At Goyllarisquisca, I went with Mr. Tweedie, the manager, to the coal mine down a steep valley 5,000 feet by a cable car Here was excellent collecting In telling Mr Philpott about it afterwards, he remarked, "In other words, you made a killing."

Although I did not suffer from soroche I noticed the rarefied atmosphere, particularly when at rest. Under these conditions my



OLD SPANISH PITS USED FOR EXTRACTING SILVER ORE
Valley north of Cerro de Pasco Heavy stone rollers crushed the ore

lungs were accustomed to slowing down, and suddenly I was not getting air enough and involuntarily must take a deep breath. This was particularly troublesome when I was going to sleep at night. Just as I was falling into unconsciousness a gasp would arouse me to full wakefulness, accompanied by a feeling of anxiety. This might continue for half an hour before I finally fell asleep. I did not observe this effect at lower altitudes, not even at 13,500 feet.

Returning to Lima I took passage for Mollendo, the terminus of the Southern Peruvian Railroad, by which I could reach Cuzco and La Paz I was fortunate in finding the hills green around Mollendo and therefore remained here two days to collect. This, like the rest of the Peruvian coast, is a desert, but occasionally at this point there are showers which bring the hills to life for a short time The verdure was found in a band only a few miles wide

MOUNTAIN ROAD, TARMA TO LA MERCED
Because of the narrowness traffic went up one day and down the next
Montaña on eastern slope of Cordillera.

On the way to Arequipa the train passes the curious crescent-shaped sand dunes that at once attract attention. These are very regular in shape, white sand against a dull flat plain, all moving in one direction, that of the prevailing wind. The dunes appear to be 10 to 15 feet higher in the middle, and about 100 feet across, tapering evenly to the two horns of the crescent.

Arequipa (7,500 feet) is a very pleasant place in a rich agricultural valley. There are three high mountains in the vicinity, Chachani (20,000 feet), Misti (19,200 feet), a regular cone, and Pichu-pichu (17,800 feet). There is at Arequipa a good observatory, a branch of Harvard University, at which Dr. Bailey was director.

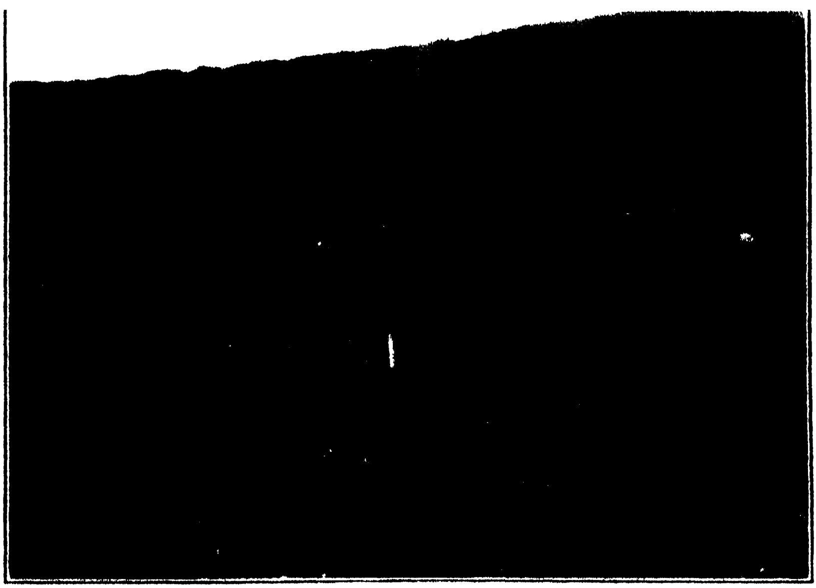
PUNA OR PÁRAMO AROUND CERRO DE PASCO, 14,000 TO 15,000 FEET
Moss grass in foreground (*Aciachne pulvinata*).

A HERD OF LLAMAS, CERRO DE PASCO
They carry loads of about 75 pounds and travel 10 or 12 miles a day.

THE COMPANY HOTEL AT CERRO DE PASCO, 14,300 FEET

I had a letter of introduction to Mr. Delgado Vivanco, from his brother, who was a classmate of my son's at the University of Maryland. Mr. Delgado arranged to take me on a day's ride into the country and was to call for me the following morning at 8 o'clock He arrived promptly on time—American style as he explained to excuse his promptness

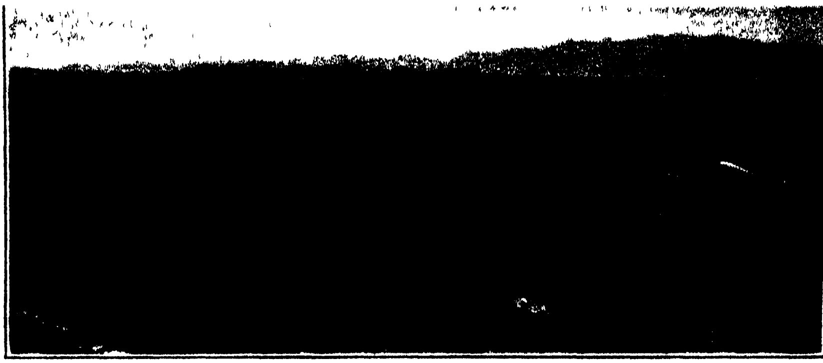
My next stop was at the new Experiment Station at Chuquibambilla, on the high plain north of Juliaca. The railroad branches at the latter place, one part going to Cuzco and the other to Lake Titicaca and on to La Paz Colonel Stordy, the director, was my host. The farm or ranch has about 18,000 acres with about 15,000



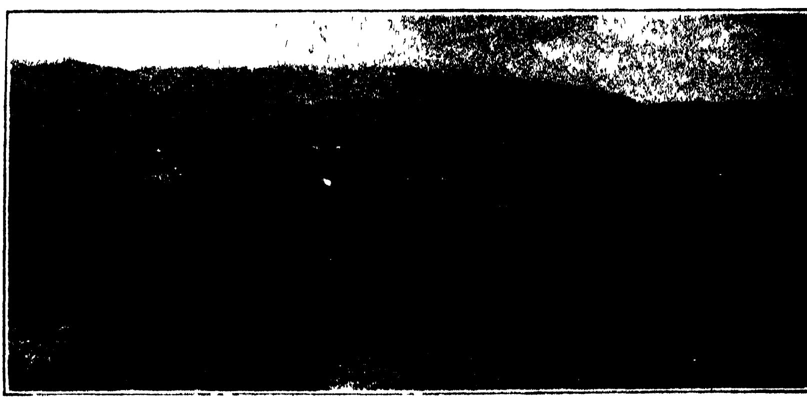
Moss Grass (*Aciachne pulvinata*)
at Cerro de Pasco, 14,000 to 15,000 feet, a pen knife in a tussock to indicate size. Note the tendency to form fairy rings.

sheep. The altitude is about 12,500 feet and the conditions are similar to those at the Atocsaico Ranch. There is a high plain from Lake Titicaca to La Raya, 12,500 to 14,000 feet altitude, about 100 miles long. It was difficult to realize that we were riding over a plateau nearly as high as Pike's Peak. The station is provided with modern equipment and is well stocked. The Peruvian government is to be congratulated upon the successful operation of this station. I had the unusual experience of playing tennis here and later at La Paz at altitudes between 12,500 and 13,000 feet.

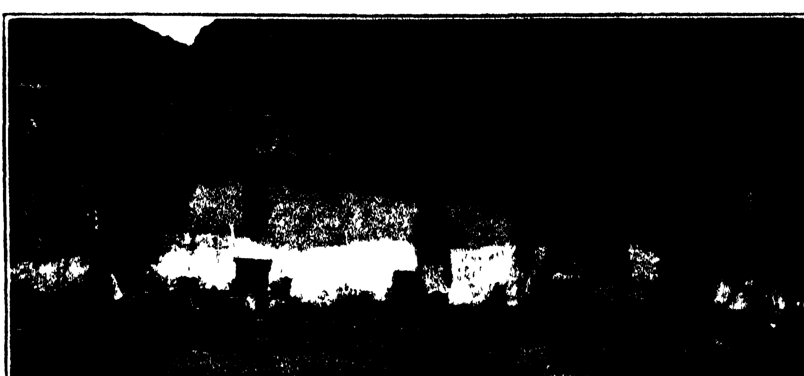
After three days pleasant stay here I went on to Cuzco, going over the pass at La Raya and down into the next valley, the city



THE PUNA OR PLATEAU AT CHUQUIBAMBILLA EXPERIMENT STATION, 13,000 FEET
Ichu grass in foreground (*Stipa ichu*)

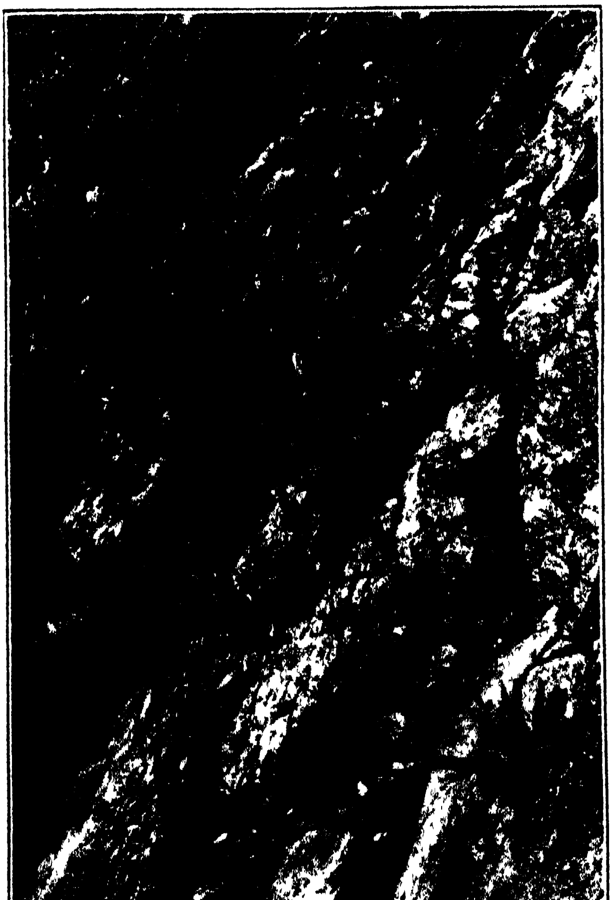


SHEEP AND YOUNG LAMBS ON RANGE AT CHUQUIBAMBILLA, 13,000 FEET
Excellent grazing throughout the year.



HOTEL AT OLLANTAYTAMBO, NORTH OF CUZCO
Llamas at rest in the plaza.

being about 11,000 feet altitude. La Raya is on the watershed that divides the rivers flowing south into Lake Titicaca from those flowing north into the Amazon As one descends toward Cuzco there come to view cultivated crops at about 13,000 feet, barley and beans (called here habas, the European broad bean), and a



CLIFFS NEAR OLLANTAYTAMBO
with cactuses and other xerophytes.

little lower potatoes, alfalfa, wheat and corn (first at 11,600 feet).

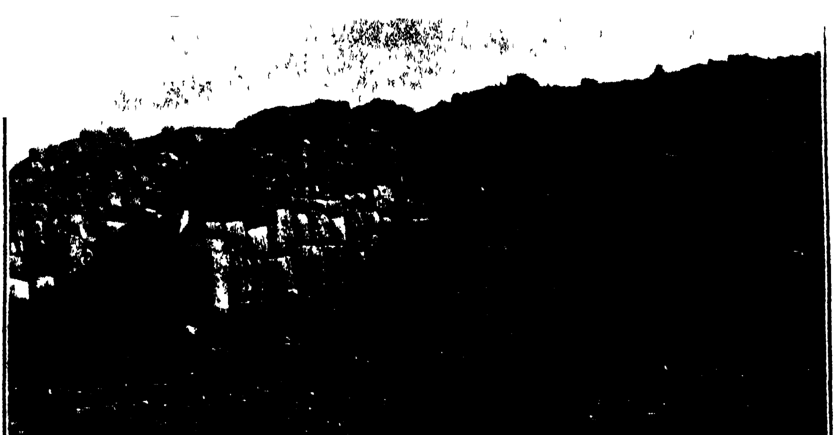
The visitor in Cuzco, even a botanist, steps aside long enough to examine the Inca ruins All over the city one sees the foundation walls of buildings destroyed by the Spaniards. At a glance the large-stoned Inca walls can be distinguished from the modern walls above them. On the hills outside the city are the ruins of a large fortress of which I took several pictures Some of the stones are of immense size—one is said to weigh 361 tons. There are

A COLUMNAR CACTUS SUPPORTING NUMEROUS TILLANDSIAS
Ollantaytambo.

several stones measuring 15 by 12 by 10 feet, and one 27 by 14 by 12 feet (according to a work describing the ruins). The most striking feature of the walls is the accuracy of the workmanship. The stones are fitted together with curves and angles, so perfectly that a knife blade can not be thrust between, and yet no cementing material was used.

There is a new railroad under construction from Cuzco down the valley north to Santa Ana Trains now run nearly to Ollantaytambo. I was fortunate in getting in touch with the officials. Through the courtesy of Sr. Almenara Butler, Sr. Romero Sotomayor, the engineer, and Sr La Torre, I was able to go to Ollantay-

STONE WALL, CUZCO, COVERED WITH CACTUS TO KEEP OUT INTRUDERS
Eucalyptus Grove.



A PART OF THE RUINS OF THE INCA FORTRESS AT CUZCO
The larger stones weigh many tons.

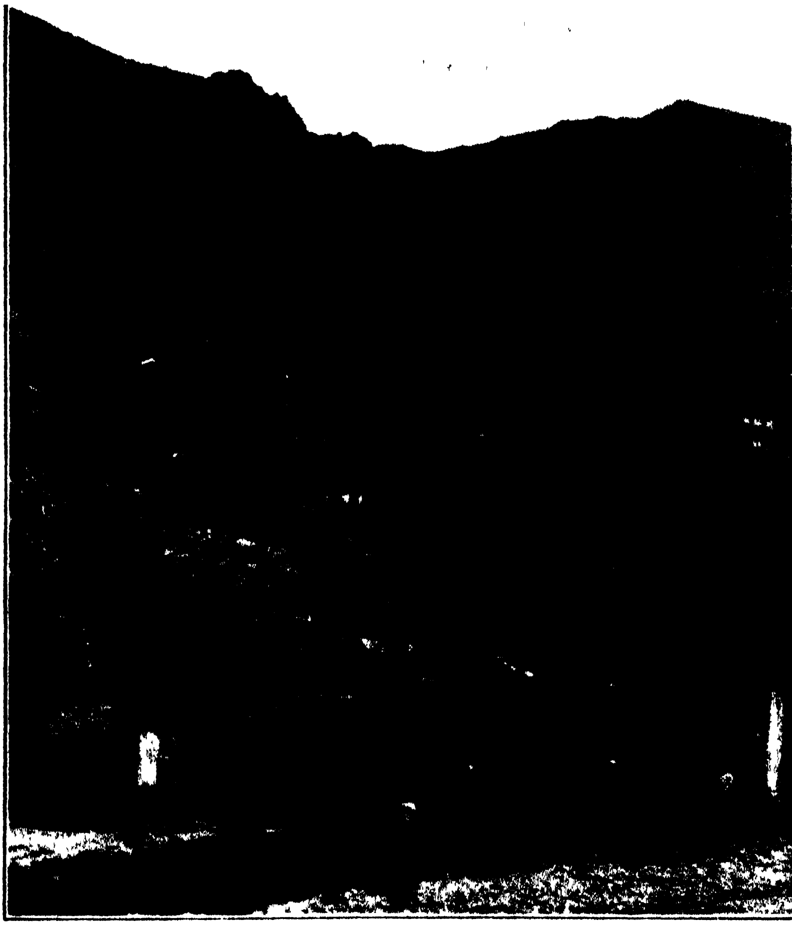
A STONY HILL BETWEEN THE FORTRESS AND THE QUARRY FROM WHICH THE STONE CAME

It would appear from the striated ridges that the stones were drawn over this hill.

tambo In company with Sr La Torre, who was paymaster, I went by horse, about 15 kilometers further, he, with his saddlebags full of silver, paying the workmen who were grading for the road.

A NEAR VIEW OF A PORTION OF ONE OF THE WALLS OF THE FORTRESS AT CUZCO

The stones are fitted very accurately and without cement. A drainage hole is shown.

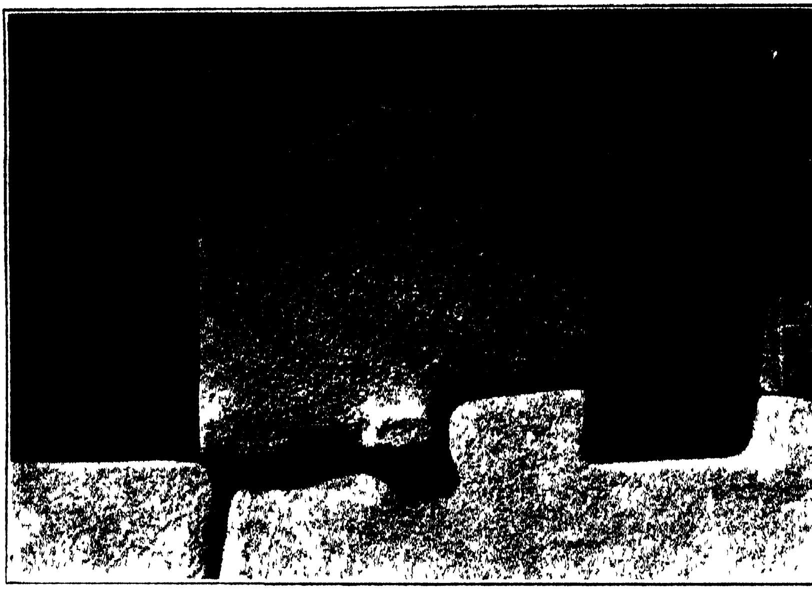


OLD INCA TERRACES AT OLLANTAYTAMBO

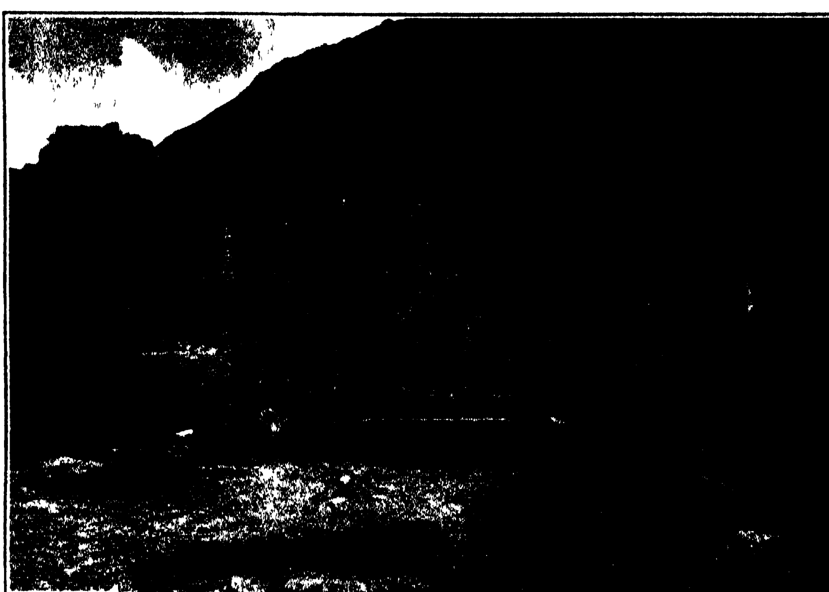
The cultivated fields, now abandoned, were carried up the slopes on these terraces and irrigated.

On the train a talkative gentleman told me many things about the places I would visit My knowledge of Spanish is not excessive and there were two key words that I did not recognize. So I looked these up in a pocket dictionary. Ah! pulga and piojo, flea and louse! There were many of these where I was going and I must be careful.

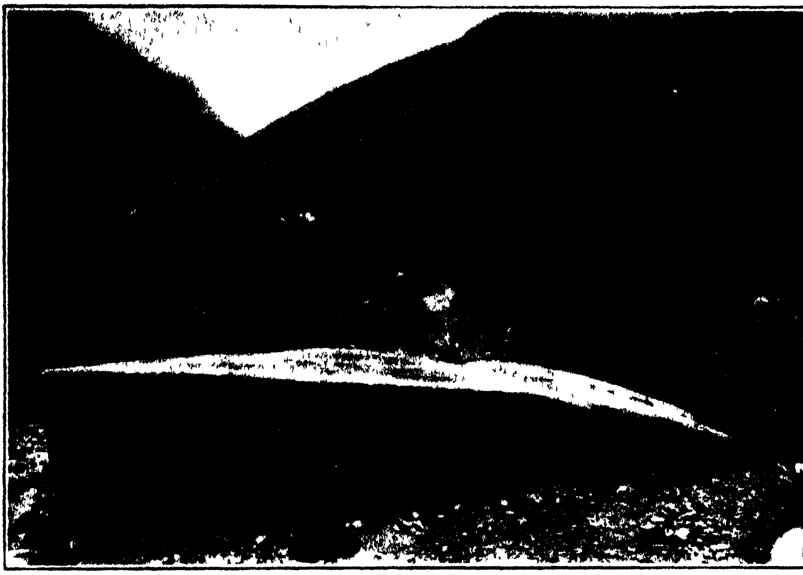
While climbing over the rocky cliffs at Ollantaytambo I stumbled and, putting out my hand quickly to save myself, thrust it into a clump of cactus (Opuntia) with barbed spines. I removed all the spines I could but many were broken off below the surface and these gradually worked out during the next two weeks. But at one place



A CLOSE VIEW OF A STONE IN A WALL OF THE RUINS AT OLLANTAYTAMBO
Showing the exactness of the fitting No cement was used.



IMMENSE STONES ON THE TOP OF A HILL AT OLLANTAYTAMBO
Part of Inca ruins similar to those at Cuzco.



An Old Inca Road, Ollantaytambo

The stones were transported over this road from the quarry many miles away. This stone was abandoned The Incas had no beasts of burden and no iron.

my finger became badly infected and I was obliged to perform an operation on myself I always carry with me a pocket dissecting case and a few simple medicines including iodine. I cleansed the surface and the scalpel with iodine, cut deeply and applied iodine. Fortunately the infection was destroyed and the wound healed One of the anxieties of the traveler here is to keep well, for outside of the cities there are no physicians.

There are more Inca ruins around Ollantaytambo, similar to those around Cuzco There are also many old terraced fields on the steep hillsides, stone walls, one above the other, with a few feet of level soil between, stretching far up the slopes. The terraces were irrigated by the Incas but are now abandoned. Yet the present inhabitants terrace and irrigate extensively.

Returning to Cuzco I made preparations for my journey to La Paz.

THE PHYSICAL BASIS OF DISEASE

By THE RESEARCH WORKER
STANFORD UNIVERSITY

VI ABNORMAL FUNCTIONAL ACTIVITY

"I HAVE but one more group of diseases to present," said the research worker, as the men returned from the observation car, "diseases due to abnormal activity of important organs of the human body not caused by demonstrable changes in the structure of these organs "

"You mean normal organs can produce disease?" said the manufacturer

"I purposely used the words 'demonstrable changes in structure ' It is possible structural changes may exist not detected by present microscopic methods Improvements in microscopic technic in the past have often led to the discovery of structural changes not suspected by earlier workers

"Abnormal activity of an apparently normal organ may be caused by numerous factors Among these are chemical over-stimulation or chemical depression of the organ Abnormal nervous impulses going to the organ may also cause unusual activity The abnormal nervous impulses may of course be of purely psychical origin "

"Then you do admit disease may be of mental origin," said the lawyer "I thought medical men looked upon such claims as pure bunkum "

"The activity of many organs of the human body may be sufficiently modified by purely psychical factors to cause disease. The conflict between biological science and 'spiritual healers' is not over this point It is over the claim of these 'healers' that all diseases are the results of abnormal psychical or 'spiritual' forces. Particularly their claim that all diseases can be cured by altering these forces They are apparently ignorant of the well-known structural changes in the majority of human diseases."

"Christian Scientists claim they have revelations in advance of medical science," said the lawyer

"The beliefs of Christian Scientists, so far as they relate to the cause and cure of human disease, are not new revelations in advance of biological science. They are really curious survivals of primitive conceptions, discarded by biologists centuries ago. All

primitive people look upon disease as the result of abnormal 'spiritual' forces. Treatment consists in attempts to expel invading demons, or propitiate angry deities Christian Scientists have merely reworded these primitive conceptions in terms of orthodox Protestant Christianity."

2

"Probably the simplest example of abnormal activity of apparently normal organs is abnormality in the action of the sweat glands The sweat glands, as you know, have a definite rôle in the heat regulation of the body, requiring accurate adjustment between the temperature and the amount of perspiration Abnormal chemical factors may cause an overactivity of these glands, with excessive perspiration on the body as a whole, or on certain skin areas Abnormal neurotic factors may produce the same effects This is a familiar phenomenon in fear and certain other emotional states Highly neurotic individuals often suffer from constant or intermittent dampness of the body as a whole, or of certain skin areas Or, they may have the opposite phenomenon, constant or intermittent dryness of the skin

"More important are the abnormalities in skin circulation. The amount of blood flowing through the skin varies from time to time This variation is brought about mainly by relaxing or constricting the skin blood vessels Certain chemical substances injected into the skin will throw the blood vessels into such extreme state of constriction that local circulation practically ceases Electrical stimulation of certain nerves may produce the same effect. In highly neurotic individuals it occasionally happens that neurotic narrowing of the skin blood vessels is sufficiently prolonged to cause marked changes in the nutrition of the skin, unpleasant tingling sensations, even pain In extreme cases gangrene may result This gangrene is one of the best illustrations of structural changes in the human body produced by abnormal nervous factors "

"Psychical gangrene," said the lawyer. "That must explain the miraculous 'wounds of Christ' in religious fanatics."

"Many modern cases of alleged miraculous appearance of wounds on the hands, feet and side during religious excitement or religious mania have been investigated. In practically all cases in which unbiased investigation was possible, the wounds were shown to be due to conscious or unconscious self-mutilation. The location of the wounds is not such that they could be readily produced by neurotic constriction of local blood vessels. Of course, medieval cases were not investigated.

"In place of a local narrowing of the blood vessels, a local dilation may take place, causing redness and swelling of the skin. You

probably know individuals who suffer from such blotches of redness and swelling after eating certain articles of food. These food idiosyncrasies are readily reproduced in animals. The idiosyncrasy is due to chemical abnormalities."

"'Chemical abnormalities!'" interrupted the lawyer. "Our Boston friend would say 'spiritual abnormalities.' Aren't both expressions synonymous with ignorance of the real cause of the idiosyncrasy?"

"If blood is drawn from an animal in which an idiosyncrasy to a certain food has been artificially produced, and this blood is injected into a normal animal, the normal animal will show the same idiosyncrasy. Distinct chemical differences can be shown to exist between the blood of this animal and normal blood. The idiosyncrasy is believed to be due to these chemical differences."

"Probably the most interesting psychical disturbance in external parts of the body is psychical, neurotic or hysterical disturbance of skin sensation. One of the commonest forms is a partial or complete loss of sensation in certain skin areas. A leg, for example, into which pins can be inserted without the knowledge of the individual."

"Don't see how such a thing is possible with a normal brain and normal skin," said the manufacturer.

"The loss of skin sensation is in some way connected with the psychology of consciousness. Most of our skin sensations normally fluctuate between the conscious and the unconscious, depending largely upon attention. One can easily conceive the hysterical loss of skin sensation to be due to an exaggeration of this normal fluctuation. Loss of sensation in certain skin areas is often likened to a condition of sleep in certain portions of the brain. This, of course, is merely a figure of speech. The underlying cause is unknown.

"The numb areas usually show marked variations in size, shape and location from day to day. The numbness may persist for months or it may suddenly disappear under emotional excitement. Similarly, psychical, neurotic or hysterical losses of sensation may take place in the special senses—psychical deafness, neurotic blindness, hysterical loss of smell. These disturbances also may disappear under emotional excitement."

"That must explain the alleged religious cures of blindness," said the manufacturer.

"The only authentic modern cures of blindness under mental therapy, religio-therapy and other forms of emotional appeal are

cures of psychical, neurotic or hysterical blindness. There is no case on record of blindness due to structural defects cured by these methods.

"Psychical, neurotic or hysterical factors may produce the opposite effect, exaggeration of the normal skin sensations. Probably the commonest form is the development of certain skin areas in which the slightest touch brings forth disagreeable sensations, even pain. In extreme cases, excruciating pain may be felt with no demonstrable external stimulus. Such areas of tenderness or pain are usually interpreted by the individual as indices of underlying organic disease."

"Is it known how these false sensations are produced?" asked the manufacturer.

"Too little is known of the psychology of consciousness to adequately explain these sensations. Normal skin sensations can be magnified in consciousness, even to the point of discomfort, by directing the attention to certain skin areas. Memories of former pain probably play a rôle. Twenty years ago I had a couple of teeth extracted for alveolar abscess. I have but to direct my attention to that side of my face to feel again the toothache of my early manhood. The dull local pain may be sufficiently strong to be a real discomfort. I am often conscious of this pain when overfatigued or emotionally upset.

"The areas of neurotic tenderness may vary in location from time to time. The tenderness may persist for months, or may disappear under emotional excitement. Similarly, heightened sensations, even false sensations of sight, hearing, taste and smell may be produced by neurotic factors, with no demonstrable structural changes to account for them."

4

"Probably the most dramatic functional disturbances in external parts of the body are psychical, neurotic or hysterical disturbances in the muscles. One of the commonest is an increased sense of muscle fatigue. In extreme cases, painful muscular weariness on exertion, incapacitating an individual for physical work."

"I've employed some of these guys," said the manufacturer. "Born tired. No sympathy with them."

"We all show this phenomenon to a minor degree—the sense of bodily weariness on disappointment, discouragement or after business reverses. If you knew the psychical factors causing the exaggerated fatigue sense in these 'guys', you might feel sympathy for them.

"Somewhat less common are the psychical, neurotic or hysterical paralyses. Loss of the use of an arm, a leg or of half of

the body. Hysterical paralysis is one of the common results of industrial accidents. It was very common with soldiers during the late war."

"I bet these soldiers were given a swift kick by the military authorities," said the lawyer.

"On the contrary, they received serious, even courteous treatment In England, for example, a certain hospital was set aside for their care. It was found that hysterical paralysis, even of long duration, could usually be cured in a few hours by carefully explaining to the individual the nature of his paralysis, showing him the physiological tests by means of which structural defects were ruled out, and getting his intelligent cooperation in an intensive reeducation of his muscles. A soldier who had not walked for a year might be brought to the hospital on a stretcher in the morning and be out playing tennis in the afternoon. Slightly wabbly, of course, from motion pictures exhibited in this country by the British military authorities; but back at the front in a month's time."

"A logical field for Christian Science," said the lawyer.

"The alleged miraculous cures of paralysis under various forms of religio-therapy are all cures of psychical or hysterical paralysis. There is no case on record of paralysis due to structural defects cured by these methods. Religio-therapy might be a logical treatment for such cases, provided all physicians and all patients were sincerely convinced of the truth of the religious doctrines involved. So long as these doctrines are regarded with skepticism by an appreciable number of people, the method will not be generally applicable. Modern methods of intellectual appeal are equally efficacious.

"Other striking psychical, neurotic or hysterical disturbances of the muscles are the various uncontrollable twitchings, jerkings, tremors and complex muscular movements. These neurotic manifestations may also vary from time to time. They may disappear under emotional excitement. Most of us show minor forms of this phenomenon, being rather 'jerky' when over-fatigued, or after loss of sleep."

5

"Functional disturbances similar to those of the external parts of the body are common in internal organs. We shall only have time, before the dining car opens, to take up two or three examples.

"Probably the simplest example is abnormal activity of the bronchi in certain types of asthma. This type is easily reproduced in animals. Guinea-pigs, for example, readily develop an idiosyncrasy to certain foods. On injecting these food materials

into artificially hypersensitized guinea-pigs, violent asthmatic attacks occur, often sufficient to cause death within a few minutes. Autopsies show that this death is due to a sudden constriction or narrowing of the smaller bronchi, preventing the entrance of air into the lungs. The constriction is brought about by abnormal chemical reactions, stimulating the bronchi into prolonged spasmodic contractions.

"In the same way abnormal chemical reactions can produce disturbances in other organs of the body, sufficient to cause distressing symptoms, even death—gastro-intestinal symptoms, disturbances in circulation, altered urinary excretion, unconsciousness. Abnormal chemical phenomena of this nature constitute my own particular field of research.

"Equally striking disturbances of apparently normal internal organs may be produced by psychical, neurotic or hysterical factors. Probably the simplest illustration is psychical disturbances to digestion. The amount of each digestive fluid is normally adjusted to digestive needs, the adjustment being largely automatic, depending upon the volume and nature of the food. The amount of each digestive fluid, however, can be modified by psychical factors independent of digestive needs. The flow of saliva, for example, is greatly increased by thoughts of food. Salivary flow may be almost completely stopped by fear. I believe psychical suppression of saliva has been used in the detection of crime, the guilty individual being unable to eat dry foods such as crackers."

"The test doesn't work," said the lawyer, "except in highly impressionable individuals."

"Most of the neurotic disturbances we are considering occur in individuals of this type.

"Psychical factors may in the same way modify the secretion of the internal digestive fluids. A good illustration is the increased secretion of mucus in the digestive tract in certain neurotic conditions. A small amount of mucus is normally secreted as a lubricant to the intestinal canal. In certain neurotic conditions large amounts of mucus may be discharged with the intestinal contents, stringy masses, even tubular casts of the intestine resembling sloughed-off layers of intestinal lining. These mucus discharges are often interpreted by the individual as grave intestinal disease. The discharge may vary in amount from time to time or may completely cease under improved psychical conditions.

"Psychical factors often produce the opposite effect, decreased gastro-intestinal secretion. The gastric juice, for example, may be greatly reduced in amount. Or there may be a reduction in one or more of the important components of the gastric juice. One

of the principal components, as you know, is acid. This acid acts as a food preservative. A reduction in the amount of gastric juice or a reduction in the percentage of acid in the juice, tends to allow fermentation and putrefaction to take place in the stomach, with the formation of gases and other disagreeable products. This is my own favorite form of digestive upset after loss of sleep, disappointment or domestic friction.

"Psychical factors may produce equally striking digestive disturbances by modifying the motility of the digestive tract. The passage of food is brought about, as you know, by orderly automatic expansions and contractions. These movements may be greatly increased by psychical factors. The involuntary passage of the intestinal contents as a result of fear is a familiar example. The commonest effect in neurotic individuals, however, is a partial or complete cessation of movements. The resulting stagnation of food leads to fermentation and putrefaction, even though the digestive fluids may be normal.

"I have a friend," said the manufacturer. "Hard-boiled business man. Has nausea, vomiting, headache for two or three days after every quarrel with his wife."

"In the same way, psychical, neurotic or hysterical factors may produce overactivity or underactivity of other internal organs, sufficient to cause serious symptoms. Hysterical suppression of urine, neurotic changes in heart action, psychical increase in internal secretions."

"How about hay fever?" asked the lawyer.

"A certain percentage is due to chemical idiosyncrasy. Abnormal chemical reactions on the nasal mucosa. Similar to the food idiosyncrasies we've already considered. In others, the symptoms are mainly, even solely of psychical origin. Patients who develop violent attacks on sight of a picture of a rose, for example. Or who develop symptoms at a certain definite date each year."

"That must account for the success of Christian Science with hay fever," said the manufacturer.

"There is no authentic case on record of hay fever due to chemical idiosyncrasy cured by any form of religio-therapy. There are authentic cures, however, of the psychical or hysterical form of the disease. This form is also cured by other methods. I know of a case. The pompous, neurotic patient so irritated his physician that he called him a 'Blankety-blank dam' fool. Get t'hell out of my office.' The patient became so angry that his symptoms disappeared."

"Hope the physician charged his regular fee," said the lawyer.

"The patient was a very wealthy broker. The physician sent

him a bill for a thousand dollars. This so increased his anger that his cure was permanent."

"You're surely joking," said the manufacturer.

"No. I was told this as an authentic incident in the life of Dr. Osler."

"Did he pay that bill?" asked the lawyer.

"I believe a check for a thousand dollars was eventually turned over to the charity ward of Dr. Osler's hospital."

6

"These neurotic changes are such simple things," said the lawyer. "Just overactivity or underactivity. Not at all what I was led to believe by my chiropractic friends."

"So far as biological science can determine, the only effect of psychical factors on an internal organ is either to stimulate the organ to excessive activity or to reduce its activity. There is no evidence of any other influence passing to the organ through the nerves."

"What about this 'life force'?" asked the lawyer.

"The nature of the nerve impulse has been the subject of serious research. There is no evidence that 'life force,' 'mental force,' 'spiritual influence,' or 'health-producing factors' are carried by the nerves. Your chiropractic friends were probably using highly figurative language, in the same way that you might say your chauffeur 'projected his personality' into your automobile, when in reality you mean he merely turned on or off the current going to the spark plugs, or otherwise varied its intensity or frequency."

"But they claim the energy of the organs comes from the brain," insisted the lawyer.

"I fear you have misunderstood their figurative language. You might as well claim that the energy moving your automobile comes from the battery supplying electricity for your ignition system. Certain organs even may function normally, after all nerves are severed connecting them with the brain. This is true of the heart. It merely loses the power of quickly adapting its rate to the varying needs of the body. If any practitioner really claims the energy of organs comes from the brain, it is through ignorance of biological facts. Or, a deliberate attempt on his part to deceive the public."

"Are these psychical or hysterical diseases sufficiently common to be of importance?" asked the manufacturer.

"Just what percentage of disease is caused by psychical or hysterical factors is hard to say. One physician told me that 25 per cent. of his patients were of the purely neurotic type. The

commonest picture, however, is an unimportant structural disease in one organ, with the resulting mild symptoms magnified by psychical or hysterical factors. Supplemented by purely psychical diseases or disturbances in other organs. Probably half of the symptoms with which patients complain are thus produced."

"Heavens!" said the lawyer. "What an inviting field for fakes!"

"There's easy money in it," said the manufacturer.

"With your legal knowledge," added the research worker, "you could easily put over any fake you found profitable."

IN AN OLD HEALTH-BOOK

By Dr. JAMES FREDERICK ROGERS

U. S. BUREAU OF EDUCATION

THE earliest guide-books to health, published for popular reading in the English language, were given charming titles. How much more alluring, meaningful and withal dignified the "Castell of Helth," the "Haven of Health" or the "Myrrour or Glasse of Health" than "A Manual of Hygiene," "How to Keep Well," "The Human Mechanism" or the like dry-as-dust names stamped on the covers of our modern works of similar intent.

Nor is the meat of these books less interesting than the labels on their rinds, as we think the reader will allow after perusing the following fragments. However, this is already proven by the great popularity of these early books. We think we live in *the* age when health books are read with avidity, but few indeed of these modern works ever reach a second edition, while reprintings of works of a century or more since ran into the tens and twenties.

The "Castell of Helth" dates from the time when castles signified more than picturesque ruins. It first left the press in 1534 and was written by Thos. Elyot, Knight, Privy Councillor to Wolsey, an intimate of Cromwell and More, negotiator of divorces for Henry VIII, foreign diplomat and member of Parliament. This was probably the first attempt to render the teachings of Galen and other of the ancients into the vernacular and was looked upon as a double sacrilege in that this meddler with the language of medical science was a layman. Notwithstanding the fuming and scoffing of the profession, or because of it, the public read it gladly, and it soon became a best seller.

The "Haven of Health" appeared just fifty years later, at the time when Shakespeare's earlier plays were leaving the press. The author, Thomas Cogan, was in humble station, being a physician and master of a grammar school. This was not a bad combination for his pupils, and that he was deeply interested in the welfare of these young shoots he proved, not only by the writing of a guide to "The Haven of Health, made for the comfort of Students," but by bequeathing the sum of four pence (possibly all he possessed) to each boy in the school.

Cogan freely acknowledges his indebtedness to "Master Elyot his Castle of Health," but he displays more originality and independence of tradition. Medical science, like all science, still leaned

heavily on the ancients, and this Elizabethan hygienist divides his material according to the order of Hippocrates. However, he could hardly have done better, for the great Greek physician placed first in importance "labour, which in this place signifieth exercise of body and mind." And how refreshing to read here the wise words of Isocrates: "Use those exercises of the body which may rather preserve thy health than strength." As for mental exercises he advises students

> to apply themselves earnestly to reading a meditation for the space of an houre; then to remit a little their cogitations, and in the meane time with an Ivorie combe to kembe their head from the forehead backwards about fortie times, and to rubbe their teeth with a coarse linen cloth. Then to return againe to meditation for two houres or one at least.
>
> Such is the state of man and beast touching the body, that the spirites, humours, yea the sound substance of all parts doe continually waste and weare away. So that if by nourishment other like be not restored, of necessity the whole must shortly be consumed.

As fit fuel for keeping up the bodily energies Cogan recommends especially the flesh of the rabbit.

> Conie which is so plentiful a meate in this Lande, and prooved so light of digestion, is little spoken of by Galen and other ancient writers. But it is verie well prooved amongst us, that there is no meate more wholesome or that more cleanly, firmely, and temperately nourisheth than Rabbettes. And what commoditie a good warraine of Conies bringeth toward the keeping of a good house, men both of honour and worship that love hospitalitie do very well know. Which vertue being acceptable unto God, and a singular benefite of all the Countrie round about them, (the more it is to be lamented) is every day more and more neglected in England. The chiefe cause thereof (us wisemen thinke) is waste-full and sumptuous apparell, now commonly used in everie degree farre otherwise than William Rufus did, who being a King's Sonne, and the second King of this Land after the Conquest, was thought to exceede, when he bestowed a Marke upon a paire of hose, using commonly to bestow but three shillings; whose example may well be a commendation to Gentlemen in these our daies, who bestow as much upon one paire of hose, as the King did upon twentie.

Here is a hint for those who need material pabulum for their organ of intelligence:

> Pertrich of all fowles is most sooneth digested and hath in him much nourishment. It driveth away the dropsie, it comforteth the stomach, and it is said that customable eating of this flesh, comforteth the memory. Wherefore it were a convenient meate for Students, and such as be weake, and I would that everie good Student twice in a weeke in steade of his commons might have a Pertrich in his supper. Neither do I marvell considering the goodnesse of the flesh, that Gentlemen be at such cost to keepe Hawkes, and take such toyle to kill Pertriches and Fesaunts.

Of fish he remarks that

> The Whiting for wholesomeness is well entertained in the Court of England, and is now became an old Courtier. . . . The Tenche is commonly called

the phisitian of other fishes, because when they are hurt thay are healed by touching of the Tenche, and as he is medicinable to fishes so is he wholesome to man's body. . . . The Troute is so sound in nourishing that when we would say in English that a man is thoroughly sound, we use to say that he is as sound as a Troute.

"Of henne egges the choice standeth in three pointes, that they be white, long, and new." Alas, there seem to have been stale eggs on the market in those prerefrigeration days.

He "reckons it a great treasure for a Student to have by him in his closet a pound of cinnamon steeped in a gallon of wine, to take now and then a spoonful."

"Much salt will make one to look old soone," but "I have known some maidens to drink vinegar nexte their hart to abate their colour and to make them faire."

"Beans," he says, "are meate for mowers and ploughmen but not for Students." Cheese will do for the diet of laboring men but not for students, for the latter "be commonly veletudinary, that is sickly. . . . As for roasted cheese, it is more meet to bait a trap, to catch a mouse or a rat, than to be received into the bodie."

Nutmegge which be hote and drie in the second degree not only maketh the mouth to savor well but they comfort the braine, the lights, the liver, the spleen, and especially the mouth of the stomach. In my judgment it is the best spice for students of all others.

The quantity of food to be taken was considered of the utmost importance by this sixteenth century physician. It "ought of all men greatly to be regarded, for therein lyeth no small occasion of health or sicknesse, of life or death. For as want of meats consumeth the very substance of our flesh, so doth excesses and surfet extinguish and suffocate natural heat wherein life consisteth." We can not put the matter more in a nutshell to-day, nor can we give higher praise to the art of cooking than in his words, "I mention cookes often times because coquerie is a part of Physicke and a good Cooke is halfe a Physician."

The greatest occasion why men passe the measure in eating, is varietie of meats at one meale . . . yea, the more we would welcome our friends the more dishes we prepare. And when we are well satisfied with one dish or two then come other more delicate & procureth us by that means to eat more than nature doth require. . . . The surest way in feeding is to leave with an appetite, according to the old saying, "& keep a corner for a friend!"

Fletcherism was forestalled by Cogan by three centuries or more:

To chew our meate and to swallow it down laysurely is a great furtherance to well digesting of the same. And indeede it is the verie end & purpose why the teeth were ordained.

We of the twentieth century like to pride ourselves on being the discoverers of the importance of prevention of disease. A glance at this book dispels such a notion. There are, however, some remedies offered for those who have kicked out of the traces of Nature's harness. If the reader suffers from the gout he may be glad to learn that

> an old Cheese is good for something, for Galen sheweth, that an old Cheese cut in pieces, and sodden with broth of a gambon of bacon, and after stamped with a little of the broth and made in a maner of a plaister, and layd to the joynt where the gowt is, will breake the skinne, and dissolve those hard knots which the gout causeth.

This recipe must have been read with much interest, for the sixteenth century was *the* age of the gout.

For toothache "Leekes and Henbane seedes burned together and the smoake received through a funnel into the mouth on that side which aketh, helpeth the toothache." "Feverfew, pounded and laid on the wrists, will cure ague in children," and "a decoction of walnut hulls will cure against pestalence."

> The Lungs of a Foxe are medicinable for them which have sicknesse of the Lungs, being used in this manner. Take the Lungs of a Foxe and drie it to powder, and put a quarter of a spooneful in a little almond milke, or broth, and eate it, for it is verie good to preserve the Lungs. . . .
>
> The haires of the Hare burned and applyed do staunch bloud, but chiefly the haires that grow under the belly, pulled off while the Hare is alive, and put into the nosethrilles, do stop bleeding at the nose.

Of course, "the anckle-bone of the foote of an Hare is good against the cramps."

Of sleep he says

> Let your lodging be in an upper chamber: let the bedsted be large and long, and no higher than a man may easily fall into it standing upon the chamber floore. Let the bed be soft, well shaken, and made rising up toward the feet, so that the bulke or breast of the bodie may be lowest. I remember when I was at Oxford in the second yeare of the raigne of her highnesse, one M. Atkins being for disobedience put in prison in London, had a chamber to himselfe, but no bed, and at length waring wearie of the bare boards: upon a night, having gotten a cudgegll or two, fell to beating and knocking of the floore, so long and so loude, that his keeper awaked, who in a rage comming to him, and demanding whether he were mad or no, that made such a noyse? "No for sooth Maister Keeper" (quote he) "I doe but beate my bed to make it soft if it would be, for it is so hard that it maketh my bones to ake!"

While we may smile at many of these Elizabethan remedies there is plenty of wisdom in Cogan's conclusion.

> That part of Physike is more excellent which preserveth health and preventeth sickness. For as much as health is the most perfect state of man's bodie in this life and the only end and marke whereunto the Phisition directeth

all his doings, which state to continue, which mark to hit, is much better than after we have fallen and erred, and missed, eftsoones to recover the same. Even as it is better to standfast still than to fall and rise againe, better to keep still a Castle or Citie, than after we have suffered the enemy to enter to rescue it again.

That the reader may better carry with him the lessons of the book the author sums his most important teachings in the following verse:

Ayre, labour, food, repletion,
Sleepe, and passions of the minde,
Both much and little hurt alike,
Best is the meane to finde.

In these five pointes as it were in so many Lute strings resteth the whole harmonie of man's life Wherein moderation beareth the burthen of the song.

No strings have been added to the lute of health since the days of Cogan, though they have been strummed vigorously, if less entertainingly, by hygienists in each generation; and in the twentieth, as in the sixteenth century, temperance is still their refrain.

THE CENTER OF POPULATION—A PROPHECY AND ITS FULFILMENT

By Professor WALTER CROSBY EELLS
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IN *Scribner's Monthly*, the forerunner of the present *Century Magazine*, for June, 1872 (Vol. IV, p. 214), occurs an article "The advance of population in the United States," by Julius Erasmus Hilgard. This article has special interest for the scientific public to-day, due to the fact that it is exactly fifty years since its author was elected president of the American Association for the Advancement of Science. In this article that talented engineer and brilliant scientist made the first reliable computation of the center of population of the United States, and ventured a half dozen remarkable prophecies as to its future course. The recent publication of a special bulletin of the national Census Bureau, "Center of population and median lines and center of area," gives data from which it is possible to show to what a remarkable extent these predictions of Hilgard, made over a half century ago, have been fulfilled.

The first official computation of the point known as the *center of population* was made under the direction of Francis A. Walker, superintendent of the ninth census and also professor of political economy and history in the Sheffield Scientific School of Yale University. It was made expressly for publication in the first statistical atlas of the United States, which was published in 1874, and based upon the results secured in the ninth census, that of 1870. The center of population was computed laboriously for each census date since 1790, except for those of 1840 and 1850. These, although he computed them by a somewhat different method, were taken from Hilgard's article mentioned above.

Without attempting to reproduce Hilgard's tables and map, it is interesting for the present generation to read again the more significant paragraphs from his article.

> The decennial inventory of the nation forms an almost inexhaustible source from which the statistician and political economist may draw information concerning the development of the country as to its population, wealth and industry in their most varied aspects. . . .
>
> In order to get some measure of this advance, or some general idea of the rate at which the country is filling up, we will consider the centers of population at different periods and examine their progress.
>
> If the population of a country were uniformly distributed, the center of population would coincide with the geographical center, being the point upon which the area may be said to balance. . . . The center of population may be defined as the center of gravity of the population, it being, in fact, the point

in which the area, loaded with its population, each man in his place, would balance. . . .

We shall furthermore observe, before proceeding to the actual case in hand, that when the tendency is to a uniform distribution of the population, the excess of increase in the new country over that in the old settlements will in time diminish, and that therefore the approach of the center of population to that of area will proceed at a constantly lessening rate. Without entering upon an elaborate discussion of this proposition, it will suffice to say that the resulting law will not differ essentially from a movement of the center of gravity of population toward its ultimate limit, in a nearly constant ratio of the remaining distance—that is to say, if within a given period the center of gravity has advanced toward its permanent place by one fourth part of the distance at the beginning of the period, it will in an equal period next succeeding advance over one fourth of the remaining space, and so on, always assuming that the movement of population is not affected by any extraordinary disturbances.

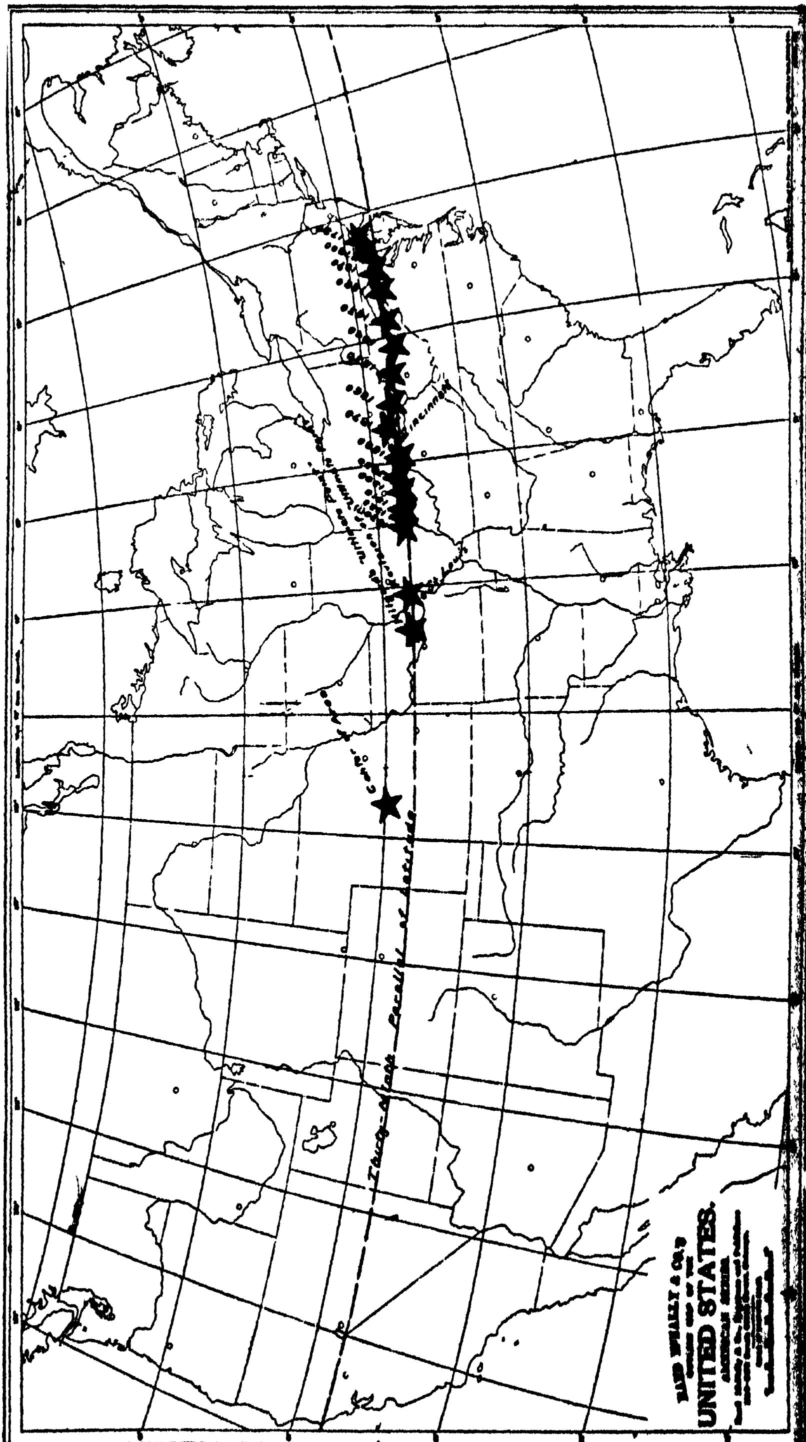
Let us now turn to a map of the United States. Its geographical center is just below the middle of the northern boundary of Kansas. Owing to the comparative infertility of the territory lying west of the meridian passing through that center, it is certain that the center of population, when a permanent ratio of distribution shall have been reached, can not lie far west of the Mississippi River; and since there is no great disparity in the northern and southern zones of the territory as to their power of sustaining a population, it will be near the middle latitude of 39°, placing it not far from the city of St. Louis, as has been claimed by persons advocating the removal of the seat of government to that place. In what time that condition is likely to be reached, we shall presently endeavor to show our readers how to estimate.

Hilgard then gives the exact location, by latitude and longitude, of the center of population, as computed by him, for the years 1840, 1850, 1860 and 1870. On this rather narrow basis he generalizes and prophesies as outlined in the following paragraphs:

The advances in the three periods were fifty-five, eighty-two and forty-six miles. The comparatively large stride during the second decade and the checked advance and more northerly direction in the third at once strike the eye. The former is attributable to the rapid settlement of California after the discovery of gold, by which a considerable population was transferred from the eastern half of the country, to its westernmost regions; the latter exhibits the loss in the rate of increase occasioned by the Civil War, especially in the South. We may safely assume that disturbing causes of such magnitude can not occur again, and that the progression will show hereafter but slight fluctuations from a regular law, since those extraordinary events have, after all, produced but very moderate inequalities.

Placing now, at a venture, the ultimate position of the center of population 600 miles to the west of its location in 1840, which will bring it between fifty and sixty miles west of St. Louis, we observe that the advance of 180 miles in the last three decades is just three tenths of the whole distance, leaving 420 miles still to be gained. But three tenths of this remaining distance is 126 miles, which may be taken as a good estimate of the advance during the next thirty years, and will bring us to a point some thirty miles south of Indianapolis.

Not wishing to stretch our inferences too far, we leave it to such of our readers as choose to perform the simple calculation for subsequent periods,



MAP SHOWING MOVEMENT OF CENTER OF POPULATION

At the time of Hilgard's predictions the positions of the center of population for 1790, 1800, 1810, 1820 and 1830 had not been computed.

which will lead them to the result that in the year 2000 the center of population will still be lingering in Illinois, some thirty miles east of St. Louis. However that may be, it is certainly safe to predict that in 1880 our center will be about 10 miles north of Cincinnati.

The Prophecies Summarized

The extracts quoted above contain the following very striking predictions:

(1) The center of population will remain near the thirty-ninth parallel of latitude.

(2) Great disturbing facts like the settlement of California (1850–1860) and the Civil War (1860–1870) are not likely to occur again.

(3) The center of population will advance in accordance with a regular law, by which in 1900 it will have moved 126 miles westward and by the same law in 1930, 88 miles farther west.

(4) In the year 2000 it will be about 30 miles east of St. Louis.

(5) In 1880 it will be 10 miles north of Cincinnati.

Fulfilment of the Prophecies

It is of great interest now, a half century after these predictions were made, to see how very strikingly they have been fulfilled.

(1) The closeness with which the center of population has clung to the thirty-ninth parallel is very remarkable. The point farthest north was reached in 1790, and the point farthest south in 1830, but the entire difference was only 21 4 miles. The farthest north since the date of Hilgard's prediction was in 1890, when it was 13 7 miles north of the thirty-ninth parallel. It has kept slightly north of the thirty-ninth parallel at every census since 1850, varying from 4.7 miles in 1880 to 13.7 miles in 1890. In 1920 it was 11.9 miles north of the thirty-ninth parallel. In 1920 it was only two miles north of its position in 1870, the latest available date in Hilgard's article.

(2) This has also been verified. The westward advance from 1850 to 1860 was about 50 per cent. greater than in any other decade, before or since; and the northward advance from 1860 to 1870 was also 50 per cent. greater than in any other decade.

(3) This is perhaps the most daring and unique of all Hilgard's predictions, since it attempts to put everything into a fixed mathematical formula. In the thirty year period from 1870 to 1900 the center of population actually advanced westward 120 miles, or 119.5 miles, to be more exact, instead of the predicted 126—a very small error indeed.

Applying Hilgard's method of moving three tenths of the distance remaining to the "ultimate point" (600 miles west of the

position in 1840), it is found that it should have moved westward three tenths of 294 miles, or 88 miles, between 1900 and 1930. In the two thirds of this period from 1900 to 1920 it has moved only 49 miles, or ten miles less than two thirds of the predicted distance.

But Hilgard's choice of a point 600 miles west of the 1840 position was somewhat arbitrary. It will be noted that he himself qualifies it by the phrase "at a venture." In the light of subsequent developments a slightly different choice of location for the "ultimate point" (to which identically the same method would apply) can be made with a slight improvement. The solution of a simple set of equations shows that if Hilgard has assumed "at a venture" a distance of 540 miles, instead of 600 miles, and then on the basis of the movement from 1840 to 1870 of 180 miles, had taken *one third* as a constant multiplier instead of *three tenths*, he would have come even closer to the actual conditions as far as they are known fifty years later.

With this slight change of constant distance, it works out thus:

1840–1870: One third of 540 miles = 180 miles.
Actual distance, 180 miles.
1870–1900: One third of 360 miles = 120 miles.
Actual distance, 119.5 miles.
1900–1930: One third of 240 miles = 80 miles.

Two thirds of this last movement of 80 miles is 53 miles, as compared with 49 miles, the distance actually travelled from 1900 to 1920. The chances seem good that it may move the remaining 31 miles during the present decade.

This revised "ultimate point," 540 miles west of the 1840 position, would be practically on the meridian of St. Louis, instead of 50 or 60 miles west of it, and thus would come even closer to making that city the logical seat of government. If it is placed on the thirty-ninth parallel, it would be about 25 miles north of St. Louis, in the southeastern part of Jersey County, Illinois.

(4) Of course the prediction regarding the position in the year 2000 can not yet be verified. But continuing the above suggested revision of Hilgard's principle, we have the following predictions until the year 2020:

1930–1960: One third of remaining 160 miles = 53 miles.
1960–1990: One third of remaining 103 miles = 34 miles.
1990–2020: One third of remaining 69 miles = 23 miles.

These results indicate that in 1990 it would probably be about 70 miles east of St. Louis, and in 2020, about 46 miles east. Hilgard's prediction of 30 miles east in 2000 may therefore be allowed to stand, with only slight modification, for another half century or more.

(5) It is rather surprising that Hilgard's final prediction of the situation only eight years after the publication of his article,

which he naturally makes with the greatest confidence, should actually have proved relatively his poorest forecast. As a matter of fact, instead of being 10 miles north of Cincinnati, it was south and west of that city by 8 miles, across the Ohio River in Kentucky. It is evident that Hilgard was justifiedly misled by the fact that from 1860 to 1870 the center of population moved northward 13 miles, a greater northward movement than ever before or since, until it was in the same latitude as Cincinnati. It was quite natural to suppose that in the next decade it would continue northward ten or twelve miles more. But its sudden jump northward was apparent rather than real, partially at least due to an inadequate enumeration. The census bureau explains it in part by the waste and destruction in the south from the Civil War, and in part (perhaps more important), to the acknowledged fact that the census of 1870 was very defective in its enumeration of the southern states, especially of the newly enfranchised negro population. That its sudden northern movement was thus fictitious rather than real is also indicated by the fact that it returned southward nine miles in 1880, when the enumeration was equally accurate in north and south.

Who Was Hilgard?

A few facts concerning this almost forgotten scientist, who succeeded so remarkably in his prophecies regarding the center of population when it was practically a virgin and untried field, may be of interest to the reader to-day.

He was born in Bavaria in 1825 but came to Illinois with his father's family when only ten years of age. He began his study of engineering in Philadelphia in 1843 and two years later entered the service of the Coast Survey under the distinguished Bache. This was the beginning of an honorable career of merit and ability with this organization lasting for over forty years and culminating all too tardily in his appointment as superintendent of the survey in 1881, a position which he held for four of the declining years of his life.

Starting as a temporary employe in field service, in the twenty years preceding the Civil War, under the magnetic encouragement of his chief, he came to occupy successively positions of greater trust and responsibility. He was a careful scientific student, as well as a successful executive. He was enthusiastic, an indefatigable worker, alert in the recognition of all that was valuable in new methods, and from his linguistic ability and wide reading thoroughly informed on the progress of geodesy and engineering both at home and abroad.

Under the stress of the Civil War, the Coast Survey was called upon for heroic and invaluable service in connection with southern

coast surveys and charts. The direction of the work was heavy, responsible and incessant; the anxiety, watchfulness and care were said to be as wearing on the chief as those of the commander of an army corps. Under this terrific strain the brilliant Bache's mind gave way, and double responsibility fell to his principal assistant, Hilgard, who met every requirement of the difficult position with credit and distinction.

After the breakdown of his chief, Hilgard might have had the superintendency for the asking, but he refused to ask for it as long as his broken chief lived, since the family of Bache were in such circumstances that his salary was necessary for their support. This disinterestedness and loyalty to his chief cost him dear. Bache lingered through four weary years, and when death finally took him there were several strong rival candidates in the field. After a prolonged struggle it was considered wise to appoint a "dark horse," Benjamin Peirce, of Harvard University, "the father of American mathematics."

It was not until 1881, after a lifetime of sacrificial and distinguished service, that Hilgard was finally appointed superintendent of the Coast Survey. He was then broken in health and suffering from the invasion of his household by death. The appointment seemed to give him new life, but it proved to be only a temporary stimulus. His working days were about over. Under the unfortunate political changes of 1884 he was compelled to sever his relations with the organization to which he had devoted a lifetime of loyal service. It was a crushing blow. Suffering with illness all the time, he never regained his health, although he lingered on until death finally came in May, 1891.

In 1862, in addition to his heavy work in the Coast Survey office, he was also supervisor of weights and measures for the treasury department. He was one of the members of the Metric Commission at Paris in 1872 and was made a member of the permanent committee. He took a leading part in preparing exact metric standards for distribution to the various states and territories. He was a member of the International Bureau of Weights and Measures, of which he declined the directorship. Typical of his many scientific contributions, may be mentioned one on the telegraphic determination of differences in longitude of Greenwich, Paris and Washington.

He was a charter member of the National Academy of Sciences and for some years its home secretary. In 1874 he was given distinctive recognition by his fellow-scientists when they elected him president of the American Association for the Advancement of Science.

THE BACONIAN METHOD OF SCIENTIFIC RESEARCH[1]

By Professor FLORIAN CAJORI

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THE Baconian method of scientific research has been appraised in the language of superlatives. On the one hand is the statement of J. G. Hibben:[2] "The revolt against the scholasticism of the Middle Ages and the fetters of the Aristotelian logic was many-voiced, culminating, however, as regards the emphasis placed upon induction as a scientific method, in the works of Francis Bacon." Similarly, T. Fowler[3] writes: "Inductive logic, that is, the systematic analysis and arrangement of inductive evidence, as distinct from natural induction which all men practice, is almost as much the creation of Bacon as deductive logic is that of Aristotle." J. Playfair[4] says: "The power and compass of the mind which could form such a plan beforehand and trace not merely the outline but many of the most minute ramifications of science which did not yet exist must be an object of admiration to all succeeding ages." Likewise, Macaulay[5] writes: "The *Novum organum* takes in at once all the domains of science—all the past, the present and the future, all the errors of two thousand years, all the encouraging signs of the passing times, all the bright hopes of the coming ages." Bacon "moved the intellects which have moved the world."

On the other hand, the weakness of the Baconian procedure is pointed out by Hibben[6] thus: "Bacon has no recourse to deduction based upon hypothesis and consequent verification. He seems to despise mathematical method as an ally of inductive inquiry and therefore has no place in his scheme for the prediction of new phenomena by means of calculation." According to the chemist, J. Liebig,[7] "Bacon meant therewith experiments which one undertakes without knowing what one is seeking, they are endeavors to

[2] J. G. Hibben, "Inductive Logic," Edinburgh and London, 1896, p. 300.

[3] T. Fowler, Art., "Bacon, Sir Fr.," in the *Dictionary of National Biography*.

[4] J. Playfair, in Encyclop. Britannica, Edinburgh, 1843, 7th Ed., Vol. I, pp. 16–17; "Dissertations," London, 1835, "Dissertation Third," p. 468.

[5] T. B. Macaulay, Essays, 1855, Vol. II, pp. 142–254 (*Edinburgh Review*, July, 1837); "Miscellaneous Works of Lord Macaulay," Vol. 2, New York, 1880, pp. 455, 456.

[6] J. G. Hibben, *op. cit.*, p. 306.

[7] Justus von Liebig, "Ueber Francis Bacon von Verulam und die Methode der Naturforschung," München, 1863, pp. 11, 47, 48.

compare without the motive therefor, and their results are therefore purposeless and aimless." "The true method does not progress, as Bacon would have it, from many cases, but from a single case; when this is explained then all analogous cases are explained; our method is the old Aristotelian method, only applied with immensely greater skill and experience. . . ." "The result reached by his method is always zero." "Such a procedure can never lead to discovery of truth." "The real method of natural science excludes chance (Willkür) and is diametrically the opposite of Bacon's method." Such is the dictum of the great German chemist. The famous astronomer George Howard Darwin[8] declares: "A mere catalogue of facts, however well arranged, has never led to any important scientific generalization. For in any subject, the facts are so numerous and many-sided that they only lead us to a conclusion when they are marshalled by the light of some leading idea. A theory is then a necessity for the advance of science." In the same vein writes the mathematician Augustus De Morgan:[9] "Bacon himself was very ignorant of all that had been done by mathematics. . . . He especially objected to astronomy being handed over to the mathematicians. . . . If Newton had taken Bacon for his master, not he, but somebody else, would have been Newton." Again we quote Liebig:[10] "The overthrow of scholasticism by Bacon was the warfare of the famous Knight with windmills."

Sir Oliver Lodge[11] writes: "He was not a scientific man, and his rules for making discoveries, or methods of induction, have never been consciously, nor often indeed unconsciously, followed by discoverers. They are not in fact practical rules at all, though they were so intended."

Such great praise and censure must signify great merits and great defects. Whichever view we adopt, one thing is clear, Bacon ranks as the earliest prominent methodologist of scientific inquiry. He represents an effort to proceed beyond the crude and slovenly inductive procedure of simple enumeration of affirmative observations. Bacon insists that men should mark when they miss as well as when they hit; they should observe many cases—the more the better. He compares his method to a pair of compasses which enables any beginner to draw a perfect circle. In his "Solomon's House" all intellectual ranks are able to contribute to discovery in

[8] G. H. Darwin's Presidential Address, *Report of British Association*, 1886, p. 511.

[9] A. De Morgan, "A Budget of Paradoxes," Chicago, Vol. 1, 1915, pp. 82, 84.

[10] Liebig, *op. cit.*, p. 55.

[11] O. Lodge, "Pioneers of Science," London, 1905, p. 136.

science.[12] His method was designed to be so perfect that genius seemed superfluous.

Needless to say that Bacon's method did not stand the test of experience. The two contributions to science made by Bacon himself were not made by his own method; they partook really of the nature of hypotheses. Bacon held the view that heat was a mode of molecular motion, and that in biological study, living objects are well adapted to experimental work, for the artificial production of variation.

Scientists seldom indulge in introspection when engaged in research. In the seventeenth century the scientific method formulated itself in the actual pursuit of scientific investigation. The method was not so much thought out as it was worked out. The Baconian method proved itself insufficient, being too narrow. The use of hypotheses and deductive reasoning was freely employed. The methodology of science, as stated by Bacon, needed revision, enrichment. This was undertaken by John Stuart Mill, who assigned to hypotheses their legitimate place. But even Mill's methodology lacks completeness. In the expositions of their methods, both Mill and Bacon understated the importance of mathematics, and of exact measurement. Neither provided a place for mathematical physics. Perhaps both also underrated the great rôle of the scientific imagination, the importance of which has been brought out so strongly by Tyndall and recently by Rutherford.

The methodology set up by Bacon is often quite necessary in a research, but is seldom sufficient. Few research men have altogether avoided it; few have limited themselves to it. Since it has been asserted by some critics that Bacon's method is useless and absurd, it may be worth while to point out cases where it has played a leading rôle. In zoology,[13] where, from Aristotle to Darwin, the main function was classification, Aristotle introduced species and varieties. Linnaeus introduced four groups, *viz.*, classes, orders, species and varieties; he divided the animal kingdom into six classes: Mammalia, birds, reptiles, fishes, insects and worms. Then came Cuvier, the founder of comparative anatomy, who divided animals into only four classes: Vertebrates, mollusks, articulates and radiates. The fundamental idea emphasized by both Cuvier and Agassiz is comparison, searching comparison. Similar remarks apply to the development of botany. In all this work the observation of resemblances and differences, the classification into groups, is the predominant feature. Substantial progress

[12] Fr. Bacon's "New Atlantis," *Works of Francis Bacon*, Vol. I, Philadelphia, 1850, pp. 255, 262 ff.

[13] See L. Agassiz, "Methods of Study in Natural History," Boston, 1869, pp. 3–23.

was slow. Then came the work of Charles Darwin. During his early studies Baconian methodology prevailed. He himself says:[14] "I worked on true Baconian principles, and without any theory, collected facts on a wholesale scale." Then, after many years of preparation, Darwin came forth with one of those great hypotheses which occasionally appear in the history of science—his hypothesis relating to the origin of species and the descent of man It infused extraordinary vitality into all fields of biology. Sir Edwin Ray Lankester's characterization of these periods is as follows:[15] "We may be thankful that at the present day we are not likely, in the domain of biology, to make the mistake (which has been made under other circumstances) of substituting the mere inspection and cataloguing of natural objects for that more truly scientific attitude which consists in assigning the facts which come under our observation to their causes, or, in other words, to their places in the order of nature. . . . All true science deals with speculation and hypothesis, and acknowledges as its most valued servant— . . . the imagination."

The Baconian method was predominant in the work of Alexander von Humboldt who, in the words of Agassiz, had a "broad knowledge of all nature" as had no other naturalist. We shall not now examine Schiller's stricture that the great naturalist lacked imagination. We observe, however, that with him hypotheses were very secondary, the passion of his career was collection of facts, description and classification. It was not his lot to advance hypotheses like that of the conservation of mass or of energy, yet who will say that Humboldt's "Kosmos" does not occupy a place of honor in the history of science?

While Bacon's method has been widely applied in biology, its use in astronomy and physics, and in other sciences which admit the extended use of mathematics, has been less prominent. In experiments on the spectral colors, Newton consciously or unconsciously used Bacon's method in part, though he also advanced hypotheses, some of which he rejected. He studied the phenomena under a variety of different conditions. If in one case it had been his good fortune to push the Baconian process one step further, the achromatic lens of the refracting telescope would have been invented in the seventeenth century, instead of the eighteenth. Newton supposed that all transparent bodies when shaped into prisms produced prismatic spectra of equal length upon a fixed screen. If he had tested this assumption by careful experiments, he would

[14] "Life and Letters of Charles Darwin," Vol. I, p. 83.

[15] Sir Edwin Ray Lankester, "The Advancement of Science," London, 1890, p. 4.

have noticed that it was false and would have been prepared to improve the refracting telescope.

An interesting application of the Baconian method, exhibiting its importance as well as its limitation, is found in the study of the aurora borealis. Among those who published observations of this strange phenomenon was Isaac Greenwood, the first Hollis professor of mathematics and natural philosophy at Harvard College. Greenwood observed the brilliant aurora borealis of 1730 at Cambridge. "I am persuaded," he says,[16] "there is no better way to arrive at the true Cause of this extraordinary Phenomenon, than by attending to the minutest Particulars and Circumstances thereof, and if what I have done contributes thereunto, I shall esteem it a sufficient Excuse for the Number and Particularity of my Notes." He took great care to record observations on temperature, wind, dew, hoarfrost, barometric pressure, time of rise and decay of the auroral displays, their color-effects, the angular altitude of the streamers, etc. But the number of possible observations is unlimited, and it did not occur to Greenwood to observe the behavior of the compass needle. Before this, Halley had noticed that the summit of the aurora lay in the magnetic meridian. In 1741, O. P. Hjorter saw by accident that during auroral displays the magnetic needle was in violent agitation; Mairan observed that the dipping needle pointed directly to the spot to which the auroral rays converge. These magnetic observations were simply a few in a large mass of miscellaneous observations. In the absence of a theory connecting the aurora borealis with magnetism they meant but little. There existed no criterion for the selection of those that were vital. Among the first to form a hypothesis was Benjamin Franklin. He had advanced his one-fluid theory of electricity during the first year of his study of electricity. He called that fluid "electric fire." In a letter to Peter Collinson,[17] he makes the guess that the aurora borealis is an electric phenomenon. He says: "When the air, with its vapors raised from the ocean between the tropics, comes to descend in the polar regions, and to be in contact with the vapors arising there, the electrical fire they brought begins to be communicated, and is seen in clear nights." Four years later he expressed himself in greater detail. Franklin's theory that the aurora is due to electric discharges in the upper air has maintained its place to our time. One can not read Franklin's scientific writings without being impressed by the extraordinary play of his imagination. When an old man, he[18] once wrote to James Bowdoin: "Our most

[16] *Philosophical Transactions*, Vol. 37, London, p. 55; Abridged, Vol. VI, Part II, pp. 115–121.

[17] "The Complete Works of Benjamin Franklin," by J. Bigelow, Vol. II, 1887, pp. 146, 253.

[18] "The Complete Works," etc., Vol. 9, p. 473.

regretted friend Winthrop once made me the compliment that I was good at starting game for philosophers; let me try if I can start a little for you.'' In the case of Franklin the use of hypotheses was second nature.

Franklin does not seem to have been familiar with the behavior of the magnetic needle during auroral displays. In fact, he had no intimation of the interrelation of electric and magnetic phenomena. In more recent time, Arrhenius advanced a much more comprehensive hypothesis, implicating our great solar luminary. We have here a fine example of how in the early stages of investigation the Baconian method was followed and how, before the time of Franklin, investigators made numerous observations, but possessed no guiding principle whatever. The Baconian procedure was necessary but not sufficient.

A fairly close approach to the Baconian method was made at one time by the chemist, Wilhelm Ostwald. Toward the end of the last century he deliberately took a ''turn toward Energetic and thereby toward liberation from hypothetical conceptions which (as he said) led to no immediate, experimentally verifiable conclusions.'' He abandoned the atomic and molecular theories,[19] ''jene schädlichen Hypothesen'' mit ''Spitzen und Haken an den Atomen,'' and took up the more direct study of experimental facts and of the resulting graphic charts. This is a striking example of theories discarded by one great worker as hopelessly misleading—theories which led other workers to the richest nuggets of new truths.

The study of earthquakes is at present in a stage where the Baconian method finds repeated application. Irregular movements of certain peaks and lighthouses in the coastal region of northern California have been revealed by careful surveys and observations which, it is said, may lead to rough predictions of the time and place of earthquakes. Seismic surveys of the world have been under way during the present century. Data are being gathered relating to double and multiple earthquakes, and relating also to the synchronism of seismic activity in different regions.

Periodigrams of earthquake frequency have been constructed. From such data it has been concluded[20] that ''one megaseism may . . . cause a relief of seismic strain throughout the world,'' that no period of from seven to twenty years existed. These are results arrived at by the Baconian method, but of course hypotheses play an important rôle in the deeper study of seismic phenomena.

It is of no little interest that the forecasting of the weather is

[19] Wilhelm Ostwald, ''Ueber Katalyse,'' 2, Aufl., Leipzig, 1911, pp. 25, 26. See also Ostwald's Faraday Lecture in *Nature*, Vol. 70, 1904, p. 15; Preface to Ostwald's ''Fundamental Principles of Chemistry,'' translated by H. W. Morse.

[20] *Nature*, Nov. 23, 1911, p. 124.

done to-day by strictly Baconian processes. Each morning several hundred of our weather bureau stations telegraph their meteorological observations. Then charts are prepared showing the change in temperature and in barometric pressure for the preceding twenty-four hours—also a general weather chart showing for each station the air temperature and pressure, the velocity and direction of the wind, the rain or snow fall and cloudiness. The forecaster notes the position of each cyclone or anticyclone and with the aid of previous charts determines their speed and direction, and predicts the events of the weather for the immediate future. It has been suggested that perhaps Swift's satire[21] on pretended philosophers who operated by the preparation and mechanical manipulation of charts was directed against Bacon's method of making discoveries by means of huge synoptic tables constructed by clerks. As a matter of fact the United States bureau conducts its forecasting along the very lines proposed by Bacon and seemingly ridiculed by Swift.

As an example of a research which led to truly important results by the use of the Baconian method alone, H. H. Turner,[22] of Oxford, has cited the work of W. W. Campbell, at the Lick Observatory, on the velocities of heavenly bodies in the line of sight, published in 1911.[23] Campbell undertook the measurements of radial velocities of stars without the guide of any hypothesis. He believed that the outcome in some way would be for the advancement of science. And indeed the classification of the results of ten years' measurements led to the capital discovery that the older a star is the quicker it moves. "The stellar velocities increase rapidly, on the average, as we pass from the blue stars through the yellow stars and on to the red stars."[24] The result was quite unexpected; it was confirmed by the researches of Kapteyn.

In view of what has been said, it appears that many, if not most, of the appraisals of the Baconian method are not in accordance with the actual facts. Bacon did not initiate a new era in experimental science. On the other hand, his method has played a significant rôle in scientific progress. The facts support the statement that Sir Francis Bacon was a herald of the dawn of experimental science, that he ranks as the first great methodologist of experimental research, that his method does not fully describe the processes usually followed by men engaged in actual research, but represents as a rule only the preliminary stages, and that in some few instances the exclusive use of his method has led to far-reaching results.

21 J. Swift, "Gulliver's Travels," Works, Vol. 2, New York, "Voyages to Laputa," Chap. 2, pp. 133, 138.

22 H. H. Turner, Address, *Nature*, Vol. 87, 1911, p. 290.

23 *Lick Observatory Bulletin*, Vol. 6, No. 196, 1911, pp. 125–135.

24 *Proceedings of the National Academy of Sciences*, Vol. 1, 1915, p. 8.

THE GLOW OF PHOSPHORUS[1]

By LORD RAYLEIGH

THE discovery of phosphorus was one of those which is associated with the transitional period when magic and science flourished to some extent side by side, and when the borderline between them was not very well defined. It seems to have been discovered by the alchemist Brand, of Hamburg. But in those days scientific discoveries were often cherished as valuable secrets, not so much for their commercial value as for the sense of superior knowledge and power which their exclusive possession was supposed to give. Scientific secrets are sometimes jealously guarded now, but not for this reason. When reticence is observed it is for the less romantic motive of commercial advantage. In the absence of this motive, the scientific men of to-day tell all they know, and tell it without delay.

The subject of phosphorus emerged into daylight in 1678, when Kunkel, who had learned the secret by word of mouth, made it public. In 1780 the Hon. Robert Boyle deposited a paper on the same subject with the Royal Society. He had worked it out anew, without more than the hint that phosphorus came from an animal source.

It was a long time before the nature of the luminosity of phosphorus was finally settled. The early investigators not unnaturally classed it with the substances which become luminous by exposure to light, such as impure calcium sulphide. This notion survives in the word "phosphorescence," which is after all purely descriptive of the property of giving light. Now, however, the word is usually reserved for the cases like calcium sulphide. Phosphorus is not commonly spoken of as phosphorescent; its luminosity, as every one now knows, is due to slow combustion in the oxygen of the air. It took a long time to prove this, and the question was still in a measure open down to the year 1874. The doubt arose partly from the extremely small quantity of oxygen necessary to make the phosphorus visibly luminous. Accidental leakages may thus confuse the question. Another puzzling circumstance was that when oxygen was substituted for air the glow was extinguished. This made it difficult at first sight to defend the position that oxygen was what was wanted to make the phosphorus glow. I have sometimes thought that it might make a plausible argument for the home-

[1] Address before the Royal Institution of Great Britain, June 6, 1924.

opathist. The less oxygen you put in the more effect it seems to have. I will show you this. We have here a large flask of 4-liter capacity. There is phosphorus on the bottom, and in order to dissolve some of the phosphorus and distribute it over a large area some olive oil has been placed on it. I can swill this oil over the surface, so that it covers a large area. At present the flask is full of oxygen, and when the lights are extinguished you can see that the phosphorus is quite dark. We will now remove some of the oxygen by means of an air-pump, and you can see that the phosphorus suddenly blazes out at a lowered oxygen pressure. The same result may be shown by substituting air for oxygen.

This is not the only peculiar thing about the behavior of glowing phosphorus. I will show you another. I have here a glass dish, with the oily solution of phosphorus which was used before covering the bottom. I remove the cover, and agitate it well, so as to bring the phosphorus in contact with air and get vigorous oxidation and a good glow. I now hold above it a piece of cotton wool moistened with bisulphide of carbon. I do not squeeze the cotton wool so as to allow liquid drops to fall from it. I merely hold it loosely, so that the vapor can stream down from it on to the glowing surface. You can see that this vapor has an almost magical effect. It stops the phosphorus glowing altogether. If we allow a little time, the small quantity of vapor gets dissipated, and the phosphorus glows again.

Bisulphide of carbon is only one example of many vapors which will behave in this way. Ammonia, camphor, ethylene, turpentine and essential oils generally will do the same thing, though they vary widely as to their effectiveness. The majority of permanent gases have little effect in this way, though I am not prepared to say what they might do at high pressures.

It will probably be admitted on consideration that the action of oxygen, which I showed you at first, is not essentially different from that of the other inhibiting substances. As will be explained shortly, the action occurs between oxygen and phosphorus vapor. A little oxygen is necessary to unite with the vapor as it comes away from the phosphorus surface, but the density that is of any use in this way is very small. If, for instance, we have a millimeter of oxygen pressure there will be in the gas space many oxygen molecules for one phosphorus molecule, and a further increase can hardly promote the combustion. The action of a great excess of oxygen, as when we admit it up to atmospheric pressure, must be something quite different. There is therefore no real paradox in the quenching by an excess of oxygen. Perhaps this analogy may help to explain what I mean: A man can not live without water; if he does not get

it he will die of thirst; yet if he swallows too much he may be drowned. The water acts in quite different ways in the two cases, and so does oxygen in contact with phosphorus.

Another very strange thing happens when phosphorus is used to get rid of the last traces of oxygen in gas analysis. Suppose that we start with air in a confined space, and put a piece of phosphorus into it. At first the light is confined to the surface, but as the oxygen approaches exhaustion, the light is seen to become diffused throughout the volume of the vessel. It is easy to understand why this happens. Phosphorus is appreciably volatile at the ordinary temperature. When the surrounding oxygen is abundant it snaps up the phosphorus vapor at once, before it can diffuse away from the surface. But when oxygen becomes scarce the phosphorus has the chance to get some distance before this happens. This much is easy to understand. But if we look closely we see that the glow is not steady, but shows moving clouds of luminosity, most curious to watch.

Unfortunately, this experiment is too faint for an audience. But any one can readily try it for himself. Nothing more is required than a piece of phosphorus stuck on a wire and introduced into a bottle—say, an ordinary bedroom decanter—which stands inverted with its neck under water.

My own work on the subject started from this experiment, which I tried to develop into something more definite than clouds of vague outline moving in an ill-defined path. The slide (Fig. 1) shows an attempt in this direction which had some success.

FIG. 1

The idea was to constrain the luminosity to move in one direction only. The horizontal tube has a layer of phosphorus lying along the bottom. The long narrow vertical tubes allow air to slowly leak in. When the oxygen originally in the tube is nearly exhausted, luminous pulses are seen to spring into existence at the side openings, to divide and to travel along the tube. Usually this happens

predominantly at one or two particular places. Pulses travelling along the tube in opposite directions kill one another when they meet.

I set up this arrangement in a dark room, and watched it from time to time. The experiment is so fascinating that one is tempted to waste a good deal of time in doing this. But after the lapse of a week or more a change was noticed. Although nothing had been touched, the movements were less lively, and the light had become stationary in places. Finally, all movements ceased.

What could be the explanation of this? The phosphorus had originally been melted into the tube under water, for safety, and the water was as far as possible poured off. But, of course, it could not be got rid of completely in that way. The oxides of phosphorus produced by the combustion are greedy of water, and thus had gradually dried the tube. On adding water the movements began again.

The next slide (Fig. 2) shows a similar tube, with only one capillary entrance at the middle. It was dried out on the mercury pump in the first instance, and filled with nitrogen. A perfectly

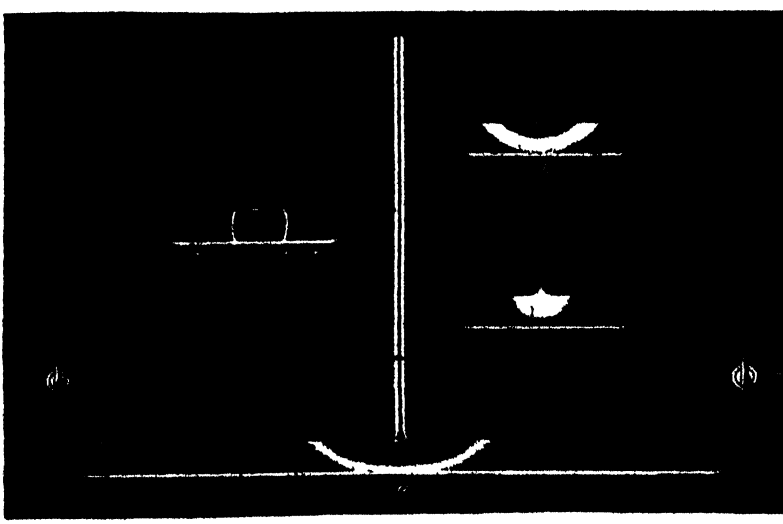


FIG. 2

steady cloud of luminosity is seen when atmospheric oxygen begins to mingle with phosphorus vapor. *a*, *b* and *c* show successive stages as the oxygen influx is increased. If a drop or two of water is added we get a succession of luminous pulses starting up at the side entrance, dividing and travelling in opposite directions along the tube (Fig. 2, *d*).

Now, what are we to think of these travelling pulses? Why does the luminosity move when there is water and remain steady when there is none?

It is evident that the travelling pulses represent the propagation of a wave of chemical action along the tube. There is a mixture of oxygen and phosphorus-vapor ready to unite. It does not at once do so, but chemical union is determined by the passage of the wave, just as in the firing of a train of gunpowder.

Nothing of this kind seems, however, to happen in the absence of water. Union occurs at once in that case, the phosphorus being consumed as soon as oxygen comes near it. The water holds up the combustion.

Now that matters have been brought to this point, you will not fail to be reminded of the experiment which I showed you before, when phosphorus was prevented from glowing by the presence of bisulphide of carbon vapor. Water, it is evident, acts like the other inhibiting substances, but less powerfully. This naturally suggests that we might get the travelling pulses on a more impressive scale by using a more powerful inhibitor than water. It is not desirable to have too powerful an inhibition, however, and I have found that camphor succeeds as well as anything. We have here a long horizontal glass tube with a mixture of camphor and phosphorus lying on the bottom. The tube is exhausted with an air pump, and air is allowed slowly to leak into it through a fine adjustment valve at one end. You will see bright luminous flashes pass down the tube at short intervals. The camphor vapor holds up the combustion until enough air has leaked in to make a mixture of favorable composition, the combustion starts, and the wave is propagated.

The period will evidently depend on how strong is the inhibiting action. I have used ammonia as a convenient inhibitor for illustrating this, for we may make its action as powerful as we please by using a more concentrated solution. The period of the flashes is increased accordingly.

If you have followed me so far, you will, I hope, have been convinced that the moving clouds of luminosity observed when the absorption of oxygen by phosphorus is nearly complete are linked up quite naturally with the existence of inhibiting substances

I shall now direct your attention to another series of experiments which allow a further unification of the same kind. They began with the repetition of an interesting observation by L. and E. Bloch, which showed that if some phosphorus was placed in a glass tube it was possible to blow the glow away from it by a blast of air, and maintain it at a distance downstream. In this form I found the experiment rather difficult of control, sometimes succeeding and sometimes failing, for no very apparent reason. It all turned out ultimately to be a matter of temperature, a few degrees making the

whole difference. The next slide (Fig. 3) shows the arrangements which were made to bring this under satisfactory control. The phosphorus is a thin flat strip, cast into a suitable recess in the side of a water tank; thus its temperature can not differ much from that of the water. The latter can be varied at pleasure by the use of ice or warm water. A flat sheet of glass is held at a distance of a millimeter or two parallel to the phosphorus slab, and the air flows

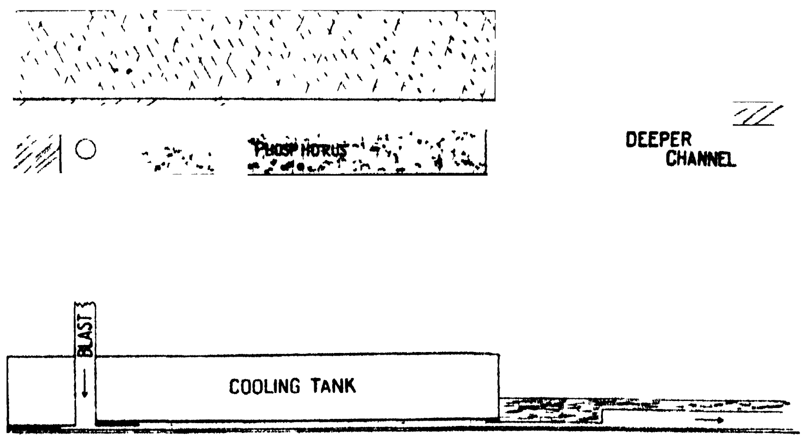


FIG. 3

between the two, being confined by suitable packing strips at the sides. The channel is prolonged downstream of the phosphorus, and is much suddenly deeper about two inches down. I should have liked to show you these experiments, but unfortunately they are not bright enough for an audience of more than five or six people, who can get quite close.

We must therefore be content with the photographs (Fig. 4, A and B). No. 1 shows how the phosphorus surface looks without any blast. V shows the glow blown right off, and maintaining itself downstream, where the channel is deepened. The dotted line (inked in on the photograph) shows the position of the phosphorus slab, which is quite dark. This is essentially the Blochs' original experiment. Interesting as it is, however, it by no means exhausts what we can learn with the arrangement described.

I examined the effect of changes of temperature, adjusting the blast in each case so that the glow was blown half way down the phosphorus strip. The velocity of blast necessary to do this was found to diminish enormously as the temperature was reduced. Thus in cooling from room temperature to near the freezing-point, the velocity diminished a thousand times. I next tried alternating the

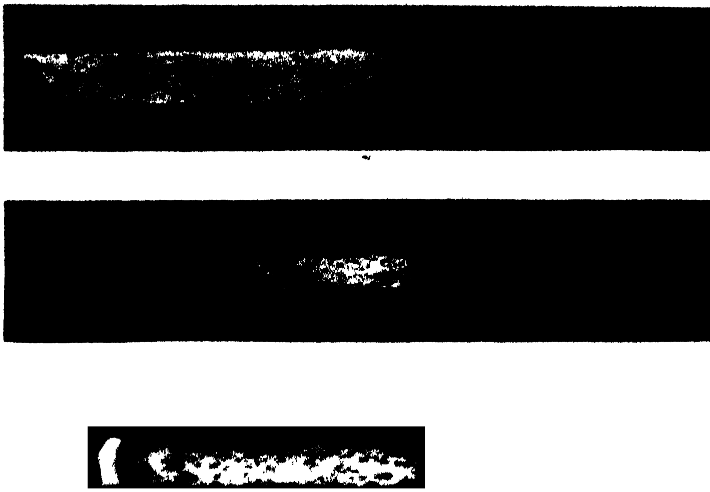


FIG. 4A

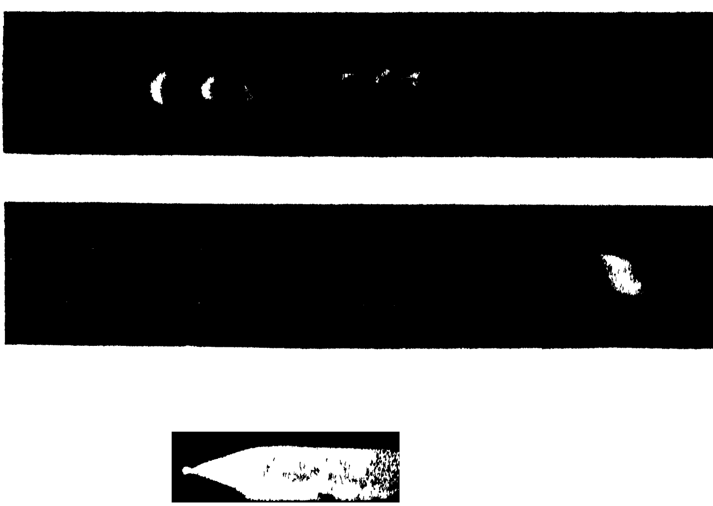


FIG. 4B

oxygen content, and found to my astonishment that enriching the air with oxygen had the same effect as cooling, and diminished the necessary velocity of blast in an equally striking degree. In both these cases the ultimate result, when the velocity had been reduced

to something of the order of 1 cm per second, was to make the glow flickering and uncertain of maintenance. On cooling a little more, or adding a little more oxygen, it went out altogether.

Now we must remember a fact, often enough insisted upon nowadays, that motion is relative. We have thought so far of the blast acting on the stationary cloud of luminosity, but we might equally regard the cloud of luminosity as propagating itself in the reversed direction through still air. When the air is much enriched with oxygen the necessary blast is gentle—in other words, the propagation is slow. It appears then that *extinction is the limiting case of slow propagation.* If we can trace the cause of slow propagation the cause of extinction will not be far to seek.

Before passing to this, however, I wish to draw attention to some curious effects met with in the course of these experiments on the blast. The same sequence of changes occurs whether we reduce the temperature or increase the oxygen content. I shall suppose, for definiteness, that the latter course is followed. When the oxygen is very little the glow tends to cling to particular spots, from which it can not readily be detached II shows this to some extent, though other experiments were made in which it was much more striking. On close examination it appeared that these special spots were depressions in the phosphorus surface, when there was partial shelter from the blast. At these places the glow started, and when once started, it infected the gas downstream of it, and made the blowing away impossible. VI shows this very clearly. In this case a hole was made intentionally.

As we increase the oxygen content a bright luminous head develops, followed by a darker space, and then uniform luminosity. This bright head no doubt represents the combustion of the stock of phosphorus vapor accumulated as the blast passes over the dark surface.

The next stage, IV, is observed when the blast is so rich in oxygen that extinction is near. You see that a succession of bright heads has now developed. They are separated by dark spaces. This photograph was given four hours' exposure, and was not easily obtained: for some movement of the luminous heads is difficult to avoid during so long a time by eye observation. The heads were seen quite regularly distributed along the column. The confusion on the right-hand side is due to unavoidable shifts.

I could only attempt an imperfect explanation of these complex effects, shown in IV, and I will not trouble you with it on this occasion. Let us limit ourselves to the question of why propagation should occur at all, and why it should be slower when excess of oxygen is present.

In the analogy of a train of gunpowder, which I have used before, there is no doubt that propagation occurs primarily because each layer that has begun burning heats up the next layer, and causes it to burn too In the case of phosphorus this explanation is hardly tenable, because the phosphorus vapor present is only a very small fraction of the atmosphere in which it is contained, and it can be calculated that it can not yield enough heat to raise the temperature more than a degree or two, which would not be enough.

We must look for some other way in which the action in one layer can help the action in the next one, and the suggestion I make is that the action is of the kind called catalytic. The products of combustion from one layer are able to promote the action in the next layer by a method analogous, *e.g.*, to that by which finely divided platinum is able to promote so many chemical actions between gases, some of them of industrial importance. It is true that this explanation is incomplete and in a measure speculative. On the other hand, as I hope to convince you, it covers many facts otherwise very hard to coordinate: and if any one is inclined to object to it, the most helpful thing he can do is to make his objection definite by calling attention to facts which are inconsistent with it, if there are any.

One of the most striking peculiarities of the kind of action I have referred to is the facility with which the catalyst is put out of order, or *poisoned* as the phrase goes. Several important industrial triumphs have depended on success in preventing this from happening. The exact condition of a surface capable of producing this effect is a very critical thing, and I believe that when the glow of phosphorus is *inhibited,* it simply means that the particles of phosphoric oxide, or other product of combustion, are spoiled, or *poisoned* by the condensation of molecules of the inhibiting substances upon them; and that this prevents them from assisting propagation. It is noteworthy that most of the inhibiting substances are easily condensable vapors, such as would be likely enough to act in this way. Oxygen is an exception, but it must be noticed, first, that oxygen will only act when moist; and, secondly, it has to be present in enormous excess—about 20,000 molecules of oxygen for one of phosphorus vapor—before it can quench the glow. Inhibitors like ammonia doubtless act by definite chemical union with phosphoric oxide.

Lastly, the view I have explained requires us to suppose that the combination is always breaking out sporadically at isolated centers, though in the presence of an inhibitor it fails to propagate itself.

I have recently been able to prove directly that this does in fact happen when oxygen is the inhibitor. When the gas-pressure was lowered the phosphorus glowed; but when it was raised again the

phosphorus went out abruptly, like a candle blown out. Nevertheless, under the latter condition, it was found by observations lasting over several weeks that a slow absorption was going on all the time, and it was found that this action occurred between oxygen and the *vapor* of phosphorus.

This whole research has been rather off the main stream of scientific inquiry at the present time; but I hope it has convinced you that there is still a fascinating field for research about phenomena which have been familiar for centuries.

JUSTICE LOUIS D BRANDEIS AND DR. JACQUES LOEB

A photograph taken at Woods Hole by Julian Scott shortly before the death of Dr. Loeb.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

THE RACE OF THE RARE EARTHS

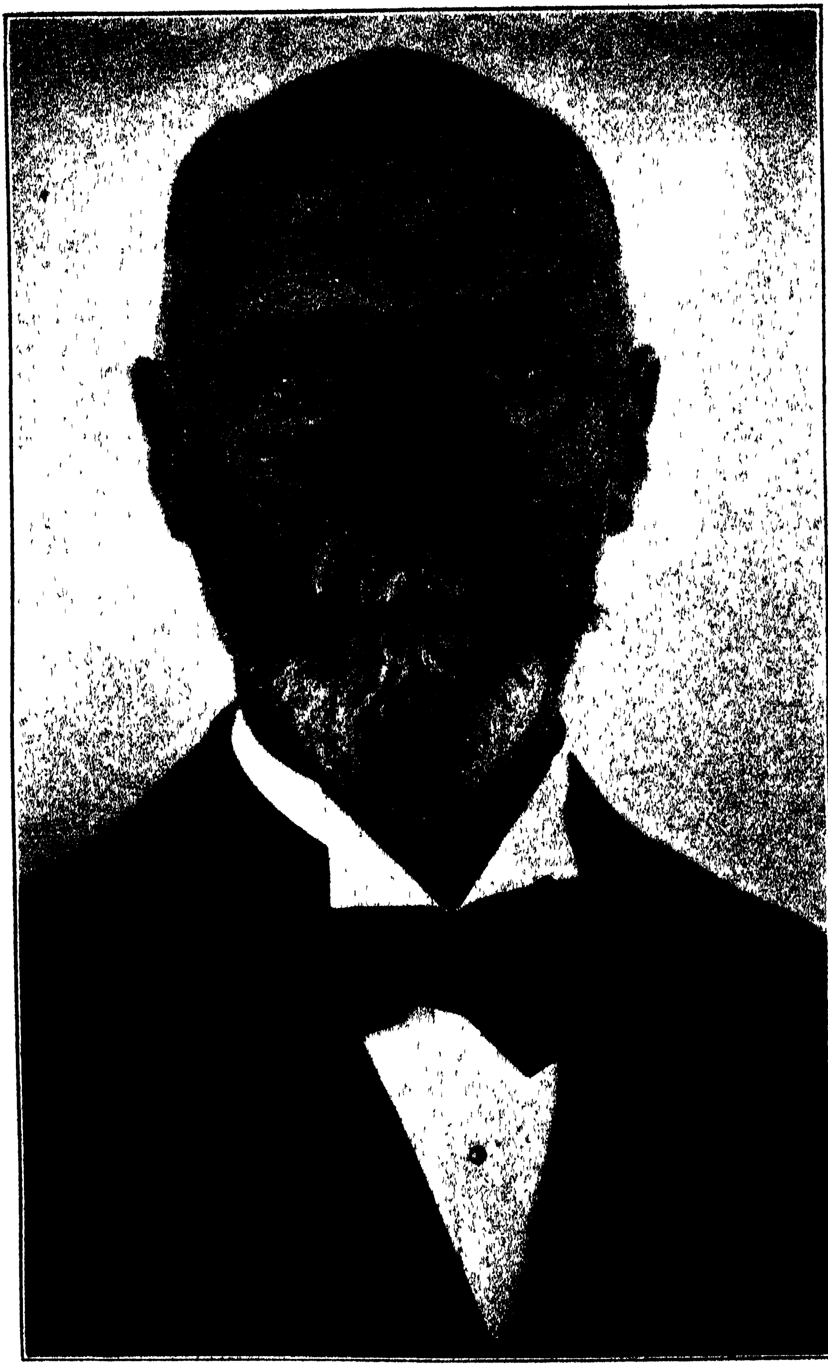
STRONGLY resembling a Marathon race is a method recently reported by a Columbia professor for separating from each other certain chemical elements that seem to have an inordinate tendency to stick together no matter what the chemist may do to break the family ties.

These elements, sixteen in number, are known collectively as the rare earths. They are really not rare at all, compared with a number of other elements, but, while the crude ores were rather easily and cheaply obtained, it required months and in some cases years to isolate the individual members in a pure condition. The consequence is that only in a few instances have scientists had the patience and the interest to carry out these fractionations which consist of from several hundred to as many as fifty thousand repetitions of the same operation. The result is that the rare earths are little known even to chemists, and since almost no pure material has been available for testing, they have found but slight commercial application.

The rare earths are like a family of brothers who have been brought up to be precisely similar in every thought and act. It is impossible to lure one away from the others by any ruse or temptation. Not that they are above temptation, however. The difficulty is that they all yield at once.

But complete identity of individuals is unknown either among the chemical elements or among human beings. The method devised by Professor James Kendall and Dr. Beverly L. Clarke is based on the fact that if all the brothers are started at the same time on a long race, slight individual differences in speed will cause each one to pass the judges' stand at a different moment. If now they are prevented from running back together, a separation is effected.

The apparatus used is a long glass tube provided with electrodes for passing an electric current of fairly high voltage through the contents of the tube. A hot solution is made of salts of the rare earths and to it is added some agar-agar, a substance which causes the liquid to set to a stiff jelly on cooling. This jelly is placed near one end of the glass tube, while on one side is placed a jelly containing an element of a speed slower than any of the rare earths, and on the other side a jelly impregnated with a faster element. The jelly is used simply to prevent the mixing that would occur with liquid solutions. The current when turned on affects the rare earth brothers and the two jailers on either side just as it would affect human beings. It creates a desire in all concerned to move away from there with the highest speed at their command. The faster and slower elements serve to prevent the rare earth section from spreading out, and so the section as a whole moves along the tube and the individual rare earths begin to arrange themselves in a series representing their respective speeds or abilities to get away from the electric energy that is urging them on. Provision is made for running the same sample through the tube



DR. WILLEM EINTHOVEN

Professor of physiology at Leyden, who has just been awarded a Nobel Prize, photographed as he sailed for home on the *Mongolia* on December 9, after a visit to the United States to deliver a series of lectures.

By United News Service.

a large number of times and when a sufficient separation has been obtained, the jelly is removed and quickly sliced into thin sections from which the individual rare earths may be extracted in a pure form.

Up to a few years ago about the only use for the rare earths outside of that of museum curiosities was in the preparation of mantles for obtaining the maximum luminosity from illuminating gas. Thorium and cerium are the metals chiefly used for mantles. With the advent of radio, however, a new use has been found for some members of this family as a coating for the filaments of the vacuum tubes, to enable radio fans to use dry cells instead of storage batteries. It seems highly probable that further research will unearth new and varied fields of employment for these interesting elements, and the new method of separation stands ready to furnish the rare earths in a much purer form, and at a minute fraction of the time and expense formerly required.

Incidentally, the new method is capable of application to other problems than that of the separation of rare earths. Hopes are entertained by its authors that through it will be found a means of purifying certain ores of radium which now practically go to waste, and thus of increasing the supply and lowering the cost of this element that is of so much importance to medicine and pure science alike.

THE GEOMETRY OF ETHICS

You may, if your arithmetic is erratic, add up a column of figures a dozen times and get different sums. Only one is correct. It is necessarily the same about the more complicated problems of life, only we can not see it so clearly. Elementary mathematics is the only science man has mastered so he can put real confidence in the results of his ratiocination.

Science, which aims at certainty, approaches it by the method of trial and error, thousands of trials, thousands of errors, before an approximation to the truth is attained. Truth is one; falsehoods are infinite. Nine tenths of the ideas that come into our heads are wrong. The object of education is to select the one that is right. Nine tenths of the impulses that beset us are wrong. The task of civilization is to suppress the nine.

No matter how complex the problem, there is never more than one right answer, one right way out, one straight and narrow path, hard to find and hard to follow, one road leading out of the maze of many false turns; all the others are blind alleys or paths that return upon themselves. It is an axiom of plane geometry that there can be only one straight line connecting two points. From the point where we are to the point where we wish to go, there is only one short straight road, all the other possible paths are more or less divergent and devious.

The rules of conduct are as invariable and absolute as the rules of geometry. The only difference is that we can not see so clearly in ethics as in mathematics. The falling of a fog makes our road obscure, but does not alter its length or direction. There is only one best move in a game of chess, whether we know what it is or not. There is only one wisest action in any emergency, whether we know what it is or not.

There are no indifferent actions, no equivalent choices. It may seem a matter of indifference which street you turn down in your morning stroll, but that is because you do not know what fate awaits you around the corner. If you turn down First Street you may be run over by an automobile. If you turn down Second Street you may meet a man who will

make your fortune. If you turn down Third Street you may catch a fatal microbe. If you turn down Fourth Street you may see the girl you want to marry.

If you knew, you could choose. But all the streets look equally inviting and not knowing which is the best you leave it to "chance" You toss up a penny, but it is not a matter of chance which face of the penny falls uppermost, for that is determined by the inevitable interaction of the forces of gravitation and rotary momentum.

Even if you could know what lay before you on each of the optional avenues, you would not necessarily be able to select the best. It may be that Second or Fourth Streets would lead you to more unhappiness than First or Third. Not knowing which is the most fortunate road you would be grateful if on that morning you should find all the others blocked by signs of "Street closed. Detour." You would be glad to be forced into good fortune if you could not find your own way. Nobody wants freedom of choice except in those cases where choice would lead him toward his goal, whatever that may be.

Nobody has a right to do wrong. Nobody but a congenital idiot would claim such a right and nobody but an incorrigible criminal would want to exercise it. Every sane man wants to do what is for his best interests and every good man wants to do what is for the best interests of others as well.

There can be no two opinions about this The only thing we disagree about is as to what is for the best interests of ourselves and society. This is due solely to our ignorance, for if we all knew always what was best to do, we should of course all want to do it But because we don't and can't always know, we have to allow considerable latitude as to thought and action, the more latitude in those fields where there is the more uncertainty There is obviously but one course that ought to be pursued or would be pursued if we could know in advance the outcome of all our options.

ANARCHY IN THE HUMAN BODY

THE human system is ordinarily a well-ordered empire. The numerous organs and innumerable cells carry out their diverse duties in close cooperation and due subordination to the central powers. If the body is attacked, say, by the cut of a knife or an army of microbes, the blood cells hasten to fill up the breach in the wall or to overpower the invading host. Because of the vigilance and well-regulated activity of the cells, the ravages of wounds and disease may be staved off for seventy years or longer. And physicians have found that they can aid the defensive forces of the body by sterilizing open wounds or injecting antitoxins to destroy the foreign invaders.

But in case of an internal insurrection, the physician is comparatively powerless for he has no medicine that will distinguish between loyal and disloyal cells since they are of the same nature and origin. Such a cellular insurrection is cancer, and that is why no cure or preventive has been found for the disease like those for diphtheria and yellow fever. A similar situation prevails in international affairs. The League of Nations can intervene in the case of conflicts between nations but is powerless to prevent internal rebellion.

The cancer cells are carrying on the same commendable activities as the normal cells. They grow and subdivide at an amazing rate, but selfishly and without regard to the commonweal. It is as if New York City should fall into the hands of anarchists who were incompetent to maintain the

public services. For a time they would thrive on accumulated wealth and incoming supplies, but transportation would break down, the water supply and sewer system would fail, food would run short, and the population would perish from starvation and pestilence. The anarchistic colony would die at its center while continuing to spread into the surrounding country.

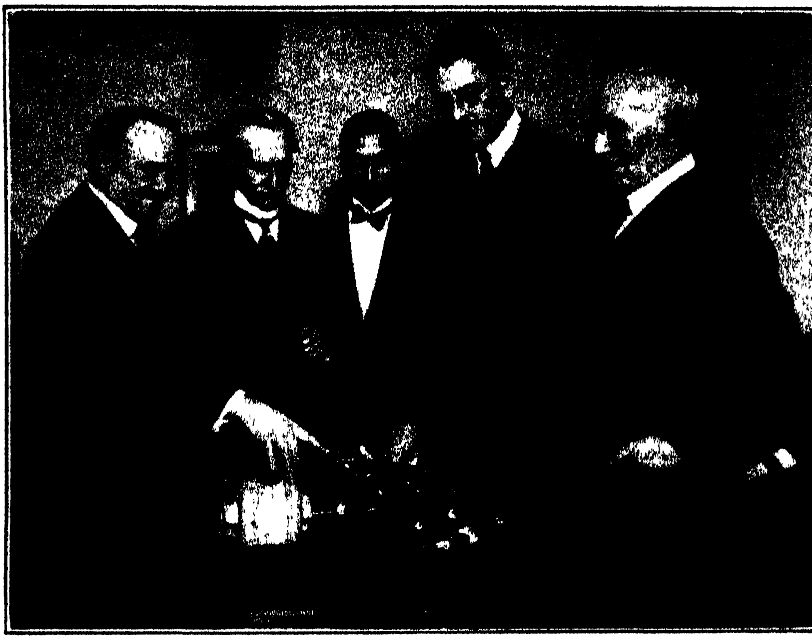
So the multiplying mass of cancerous tissue grows without developing, expands without organization, all cells of the same sort, equal in rank and alike in function; none in authority and none to obey; none to look after the interests of the community as a whole; none set to serve the rest as carriers or scavengers. So the cancerous colony, cut off from communication with general headquarters by lack of nerves, devoid of veins to relieve it of its waste products and of arteries to supply food and oxygen, dies and decays at the center, poisoned by its own pollution, while vigorously extending its conquests into the healthy tissue round about.

To "increase and multiply" is the only law recognized by cancer cells. Some break away from the parent community and start new colonies in some remote part of the body. That is why it is so difficult to cut out cancer completely with the knife. A few cells transplanted from one animal to another will flourish in their new environment. They will even grow in glass if kept warm and well fed They seem to be immortal and capable of infinite expansion so long as living conditions are favorable. In one American laboratory a single cancer strain has been kept in continuous existence by transplanting for thirty years, and it is calculated that if all the branch colonies had been allowed to grow and given a chance to expand as they would, the mass of cancerous tissue would fill the universe, all starting from some one cell that had gone wrong.

Sampson Handley says in the recent report of the Cancer Research Laboratories of the Middlesex Hospital, England: "It has to be remembered that man with his millions of cells has evolved from a single cell. It is hardly a matter of surprise if occasionally one of these millions of trained subordinate cells reverts to the ancestral, independent type, behaves like a unicellular organism, owning no allegiance to the cell community, whose ruin is the final outcome."

What starts the revolt? What is the origin of the impulse to anarchy? This remains a mystery although the problem has been the object of research in well-equipped laboratories by skilled experimenters for many years. No microbe has so far been found present in all cancers and certain to produce them. Cancer is not, as commonly said, an exclusive disease of civilized man It occurs among primitive peoples and animals, and has even been found in fishes. Cancer is apt to start at some point of chronic irritation yet not all such irritation causes cancer.

Three ways are known by which cancer is caused and by which it may be produced experimentally. One is by action of the penetrating rays of radium or the X-rays. These may either stimulate or destroy the cancerous tissue according to their intensity and duration. Another cause is a minute parasitic worm, carried by cockroaches, and when rats eat the cockroaches they are likely to get cancer of the stomach. The third cause of cancer is some substance contained in minute amount in the higher boiling fractions of coal-tar and petroleum. Workers about shale oil and tar stills are apt to get large warts on their hands that sometimes become cancerous and chimney sweeps may get cancer from the soot. Coal tar put on the skin of mice will cause cancer but not on rats.



THE RADIO PHOTO-LETTER MACHINE

C Francis Jenkins, known for his work in motion-picture projection and the transmission of pictures by radio, who is on the left, is showing his radio photo-letter machine to J. Horace Rogers, who has done important work on underground wireless and radio transmission; Alfred Stearns, in charge of radio at Washington; Curtis D Wilbur, secretary of the navy, and Emile Berliner, known for his important inventions including the loose contact telephone transmitter which is also used in radio.

Until the cause of cancer is discovered, a cure can hardly be hoped for. But there are a few well-authenticated cases of spontaneous cures, and recent experimentation points the way to a possible conquest of the disease. In the Middlesex Hospital certain hopeless cases have been treated by injecting doses of cancer cells that had been killed by exposure to radium rays, and encouraging results are reported from this treatment.

DEATH-DEALING AND LABOR-SAVING RAYS

CHEMISTS in various parts of the world are busy trying to break open the safe that contains the most wealth of any in the world. This safe is the atom. For wealth is the product of work and work is the application of energy, and the most powerful and concentrated form of energy consists of the balanced forces of the positive and negative electrical particles inside the atom.

These forces are most intense in the nucleus of the atom, the sun of the atomic system The atom of radium is in an unstable state and occasionally throws off a fragment from its nucleus with a velocity of ten thousand miles a second. This speed is twenty thousand times faster than a rifle

bullet, and consequently its energy is four hundred million times greater than that of the bullet, mass for mass.

Now if it were possible to excite a similar instability in the atoms of other elements than radium, we might get enormous streams of energy out of them. Is it possible? Most scientists to-day are disposed to doubt it.

But at least one reputable electrician, Dr. T. F. Wall, of Sheffield University, England, thinks that it can be done and he is trying to do it. His apparatus is based upon a simple principle that is familiar to everybody who has played with a coil of wire and a magnet. Sticking the magnet into the coil starts an electric current, that is to say, a stream of electrons, running through the wire, and conversely, running an electric current through the wire will create a magnetic field inside the coil.

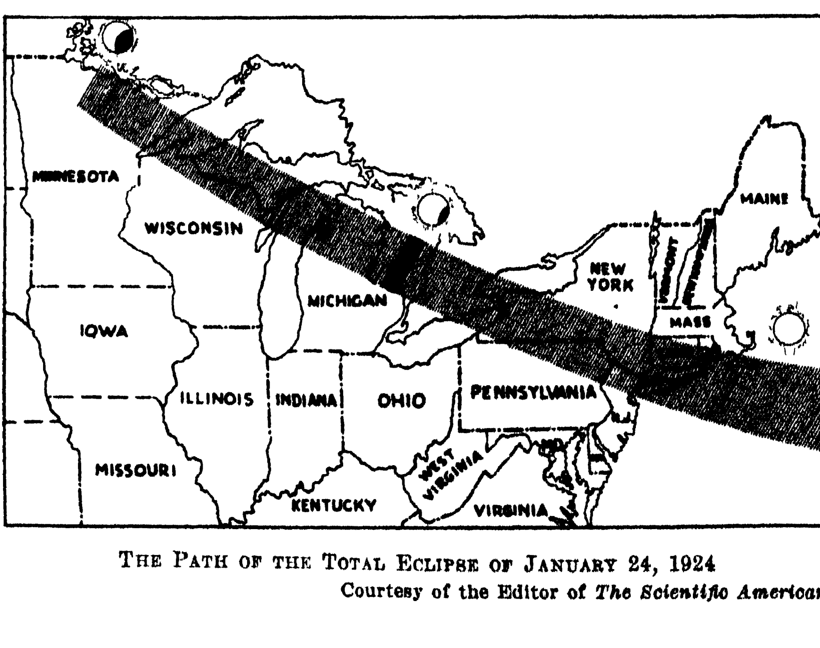
Now the electrons, revolving in their orbits around the nucleus like the current in the coil, must produce a powerful magnetic field. Conversely, we would suppose that if we brought more powerful magnetic forces to bear upon the atom, its electrons would be disturbed in their orbits and perhaps even driven out of the atomic system altogether. If, for instance, a giant star with more gravitational force than our sun should wander into our vicinity, it would create a commotion in our solar system and perhaps a scatteration of the planets.

But the magnetic field inside the atom is vastly more intense than any that has hitherto been produced artificially. How then can we hope to upset its equilibrium? But Dr. Wall has the idea that the rapid and rhythmical repetition of even a weaker power may derange the revolutions of the electrons, just as a suspended cannon ball may be set swinging by repeated taps with a light mallet.

By passing an extremely powerful oscillating current through a coil, he hopes to get a sufficiently intense magnetic field inside the coil to overpower and counteract in some measure the magnetic field inside the atoms. From static condensers of large capacity and high voltage, he obtains a current of 50,000 amperes, but as it runs only a fraction of a second, it does not burn up the wire. With this apparatus he is able to obtain a field amounting to some millions of magnetic units.

Dr. Wall is reticent about his results, but is willing to disclose the purpose of his experiment and its possibilities. In the latest number of *Discovery*, he says: "Quite frankly stated, the ultimate aim is definitely to disturb the atomic structure for the purpose of releasing some or all the latent energy of the atom."

Since he has been credited—and discredited—in the press with the design of producing a "death ray," it is well to quote his own words on this point. He says that the energy so released from the interior of atoms "presumably would be in the form of rays of energy of some possibly quite unknown type." The possibility of their application to warfare would be a serious national concern, for "it is reasonable to suppose that if intense magnetic fields are found capable of releasing the atomic energy, similar magnetic fields may provide the solution for the control, and concentration of the released energy in the form of a ray or beam like the beam of a searchlight. If this is found practicable it would probably result in a very simple control apparatus. Such a ray or beam of energy when directed on any given object would possibly be capable of yielding up its energy in the form of heat, thus superseding the use of coal, oil or other fuel. What, however, is far more probable is that new forms of motors



THE PATH OF THE TOTAL ECLIPSE OF JANUARY 24, 1924

Courtesy of the Editor of *The Scientific American.*

would be developed which would be able to use the energy of the beam directly without the need of any intermediate conversion into heat."

We must admit that Dr. Wall has reason for his surmise that in the present temper of the human race such a new found force would be first applied to the killing of human beings and the destruction of their property. But other inventions, quite as affrighting at first sight, have in time been tamed and set to the service of man. The weapons of Mars ultimately become tools in the hands of Minerva.

But it would be premature to worry over its possibilities in warfare or to rejoice over its potentialities in industry until it is proved that such a form of radiant energy can be produced in quantity from the atom and that it does not require more energy to release it than can be obtained from it.

TESTING AND TRAINING THE MEMORY

By Professor R. S. Woodworth, Columbia University

A young college freshman came to see me to ask my advice about his poor memory. His memory was so poor, he said, that he simply could not learn his lessons no matter how much he worked over them. I put him through some memory tests and found that his memory was perfectly normal. Then I asked him how he went to work to learn his lessons, and I found that he had carried over into college his high school habit of simply reading his lessons through and through in a blind passive way. A long college lesson in history he would read through once, then read it through a second time, then a third and sometimes a fourth time, and yet when next day questions were asked upon this lesson he had forgotten the answers. Now the fact was that he had not forgotten the answers, but had never known them, for he had not analyzed the reading, understood it or picked out the important points. It was a lack of good management rather than of power of memory. I advised him to read the lesson through once, then to review and analyze it mentally, and finally to consult the book again and check up his analysis. This procedure he found to save him much time and give much better results.

If you ask us what memory is, you see that it amounts to this: You do something all by yourself, which you originally needed assistance to do. If you remember a person's name you can call him by name on sight without any assistance. When you first met this person you had assistance. Some one told you his name. Good management demands that when you have the assistance at hand you should so use it as to do, right then and there, the very thing that you wish to do later without assistance. When someone has just told you the stranger's name you should look at the stranger and call him by name, either aloud or silently, and so prepare to do this very thing at some later time without assistance. This is the principle of all sound memory training.

Psychologists, after testing the memories of many people, are able to announce two very encouraging results. First, that nearly every one has more power of memory than he imagines, and second, that intensive training produces great improvement in memory. But it should be added as a very important qualification that training does not develop the general faculty of memory, but simply increases the power of doing the particular kind of memory job that is practiced.

The first step towards effective memory training is to decide exactly what sort of memory work you need to improve, so as to devote your effort to this particular job. If you wish to improve your memory for poetry, you must practice memorizing poetry. If you wish to improve your memory for names and faces, you must practice connecting the name with the face. If you wish to improve your memory for telephone numbers, you must practice connecting telephone numbers with the names of subscribers If you wish to improve your musical memory you must practice memorizing music. If your wife complains because you can not remember much of interest from your day's experiences to enliven the supper table, what you need to practice is the taking note of interesting items as they occur and then recalling these when the time comes. Great improvement can be made in any of these memory jobs, by devoting time and effort to that particular job. No doubt an expert psychologist adviser could assist any one to improve his memory work, but an intelligent person can do much for himself, once he knows that he needs to train himself for specific memory jobs, and that the problem is one of management rather than of inherent memory power.

The first step is to see exactly what memory job needs to be perfected. The second step would naturally be to proceed to practice this particular job. But just here a very curious state of affairs often comes to light. The man who says he very much desires to improve his memory yet finds it very irksome to work at the details of this particular job. In a way he is indifferent or even unwilling to do this job well. He experiences an inner resistance that interferes with his progress.

If this seems almost an impossibility, consider once more the sad case of the man whose wife finds him very unsatisfactory as a provider of interesting news. Is this the sort of man who snaps up eagerly every bit of interesting gossip or happening, and who anticipates the pleasure of recounting his news at the supper table? Does he relish the job of gathering news items for feminine consumption? Possibly not. Quite possibly he is the kind of man who thinks this beneath his dignity. He doesn't regard this as his job in any big sense. When it comes down to the actual working of this job, he rebels against it. This inner resistance is going to interfere considerably with the improvement which he might make. The chances are that he never will enter into this new game heartily, and will never become a shining example of success in this sort of memory work; but if he can overcome his own resistance it is in his power to improve. It has been done.

Poor memory is due to poor management rather than to an inferior faculty of memory. Any sort of memory can be improved if one discovers exactly what needs to be improved, and if one can play the game heartily.

THE SCIENTIFIC MONTHLY

FEBRUARY, 1925

THE STATE OF SCIENCE IN 1924

THE ELECTRON

By SIR J. J. THOMSON, O.M., F.R.S.

ELECTRONS are particles of exceedingly small mass carrying a charge of negative electricity; there is only one kind of electron, for all electrons have the same mass and carry the same electric charge. Until the discovery in 1897 of the electron, the smallest mass known to science was that of an atom of the lightest element hydrogen, but the mass of this atom is 1,800 times greater than that of an electron The mass of an electron is by far the smallest of all known masses. The electrons are the bricks which build up the atom; an atom of hydrogen contains one electron, an atom of oxygen eight, one of lead about one hundred, and so on. Differences in the number and arrangements of the electrons in the atom are supposed to account for the difference in the properties of the atoms of the different chemical elements.

Although the electron is by far the commonest and most widely distributed thing known, it was not discovered until 1897, and then in what may be called a highly specialized region. It had been shown by Plücker in 1859 that when an electric current passes through a gas at a low pressure the glass tube in which the gas is contained phosphoresces in the neighborhood of the cathode. The phosphorescence is due to something traveling in straight lines from the cathode, for if an obstacle such as a piece of glass rod is placed between the cathode and the walls of the tube a shadow of the obstacle is thrown on the wall. The nature of the "cathode rays," as the agents which produce this phosphorescence are called, was the subject of a long controversy. One view was that they arose from waves in the ether, another that they were due to negatively electrified particles. In support of the latter view were the facts that negative electricity

[1] Prepared for the Hand-book to the Exhibit of Pure Science, arranged by the Royal Society for the British Empire Exhibition.

traveled along the direction of the rays, and that the rays were deflected by a magnet; but against the view was the fact that the rays could pass through thin sheets of metal, such as gold foil. If these rays are electrified bodies, it is possible by certain methods to determine their mass, velocity and electric charge, and when this was done it was found that the carriers were not atoms or molecules, but something almost infinitesimal in comparison.

The mass and velocity of the electron were determined by measuring the deflections they experienced when acted on by electric and magnetic forces. Suppose the electron started off horizontally in a discharge tube. If it were not acted on by any forces it would strike the glass wall of the tube at a point opposite its starting point, and the place of impact would be marked by a patch of phosphorescence. If, however, it is acted on by a constant electric force X, acting vertically downwards, the electron would have a downward acceleration Xe/m (if e is its electric charge and m its mass), and would fall just as a rifle bullet shot off horizontally would fall under gravity. The vertical fall of the bullet is $g \times l^2/2v^2$, where l is the horizontal distance passed over, v the velocity of projection, and g is the acceleration due to gravity. Putting Xe/m, the acceleration of the electron instead of g, we see that the distance fallen through by the electron will be $X(e/m)l^2/2v^2$. Hence the electron acted on by the electric force will hit the glass at a point which is this distance below its original destination. If h is the deflection

$$h = \frac{X}{2}\left(\frac{e}{mv^2}\right)l^2;$$

we can measure h, X, and l, and hence from this equation we can get e/mv^2.

If instead of acting on the electron by an electric force we act on it by a magnetic one, at right angles to the direction of motion, the force on the electron due to the magnet is Hev; hence the acceleration is Hev/m, and is at right angles to the path of the particle and in the direction of the magnetic force. Now suppose we let both the electric and magnetic forces act simultaneously, and let one act upwards and the other downwards. We can adjust the two forces until the accelerations due to them just balance, and the electron will then move as if neither electric nor magnetic force acted on it, and the phosphorescence will occur on the tube at the same point as that affected by the electron before either electric or magnetic force was introduced. For the acceleration to be equal

$$\frac{Xe}{m} = \frac{Hev}{m} \quad \text{or} \quad v = X/H.$$

We can measure both X and H, and thus determine v. We have

previously determined e/mv^2, so that when we know v we can find e/m. This was found to be equal to 1.8×10^7.

Now if E is the charge of electricity carried by the hydrogen atom in the electrolysis of solutions, and M the mass of that atom, E/M can be determined by measuring the quantity of hydrogen liberated when a known quantity of electricity passes through an aqueous solution. This was done long ago, and the result was that $E/M = 10^4$. Special investigations have shown that e, the charge on the electron, is equal to E, the charge on the hydrogen ion; hence since $e = E$ and $e/m = 1.8 \times 10^7$, while $E/M = 10^4$, $m = M/1800$, or the mass of an electron is only 1/1800 of that of an atom of hydrogen.

Experiments were made on cathode rays produced with electrodes made of various metals and with different gases in the tube, but the mass of the electron and the charge of electricity it carried were found to be the same whatever might be the nature of the metal or the gas. The velocity of the rays, which was always very high—many thousand miles per second—varied with the potential difference between the electrodes. This high velocity makes the energy of an electron, in spite of its small mass, enormously greater than the energy of the ordinary molecules of a gas. Thus a comparatively slow electron, moving with a speed of 30,000 miles per second, has 250,000 times the average energy of a molecule of a gas at ordinary temperatures. It is this comparatively enormous energy which makes the detection and study of electrons easier than that of ordinary molecules.

When once electrons had been detected they were found to be very widely distributed. Thus it was found that they were given off by hot wires, and the hot-wire valves now so largely used in wireless telegraphy and for many other purposes work entirely by electrons; electrons are also given off by bodies when struck by ultra-violet light or by Röntgen rays. Radio-active bodies give off very high-speed electrons moving very nearly as fast as light. But whatever may be the means used to liberate them, or the source from which they come the electrons themselves are always found to be the same.

X-RAYS AND CRYSTAL STRUCTURE

By SIR WILLIAM BRAGG, F.R.S.

Diffraction of X-rays

There is a strong analogy between the use of X-rays in the investigation of crystal structure and the employment of light in conjunction with a diffraction grating. There is, however, a very great difference in scale, for the X-ray waves are ten thousand times

shorter than those of light. The ordinary diffraction grating consists of a sheet of metal or glass on which parallel lines are ruled, say, 20,000 to the inch. When a ray of homogeneous light is directed upon such a grating, diffracted pencils of light leave the grating in various directions according to well-known rules. That which is least diffracted we call the effect of the first order, and the others are of the second order, the third order and so on. The angles which these diffracted pencils make with the original rays are determined by two factors—namely, the wave-length of the light and the spacing of the lines on the grating, and it is possible, given a wave-length, to find the spacing by measuring the "angle of diffraction." Such a measurement is very exact. There is another well-known grating effect which is sometimes made use of. The relative intensities of the different orders, but not their angles of diffraction, depend upon the dimensions and form of the groove which the ruling diamond makes on the plate. Sometimes one spectrum is intensified by some particular characteristic in the forms of the grooves. It might be possible to work back from observations of the relative intensities to a determination of the shape of the groove.

When we turn to X-rays we find the analogue of the light waves in the waves of the X-rays and the analogue of the grating in the ordered arrangement of the crystal. If X-rays are allowed to fall upon a crystal, diffracted pencils may be emitted, and the angle which the diffracted pencil makes with the original ray depends upon the wave length of the X-rays and the spacings of the crystal. So far the diffraction of X-rays resembles the diffraction of light by a grating. There is, however, an additional effect in that the direction of the original rays has to be related to the lie of the crystal planes in different ways before any diffraction takes place at all. In the actual experiment the crystal is rotated about some important axis until the diffracted pencil of the rays flashes out and the angle of diffraction is then observed just as in the case of light.

The Units in the Structure of Crystals

The chemical molecule consists of a certain number of atoms arranged in an ordered way. When the molecules are built into a crystal they tend to an arrangement which has a higher symmetry than the molecule itself possesses. We may say that Nature puts together two, three, four or even more molecules in such a way as to make for higher symmetry. In this way she makes a unit of pattern. The units of pattern are distributed on the lines and plans of a lattice, each unit having exactly the same form, composition and outlook as every other unit; the whole structure of the crystal is an

orderly arrangement of these units. They may be considered to lie on various planes or sheets within the crystal just as the rows of trees in an orchard may be considered to lie in various rows, and each sheet corresponds to a line in the light-grating. The X-rays give the distance between sheet and sheet. They may do this for sheets drawn in various ways, and hence it is possible to determine the arrangement of the units in the crystal—that is to say, the form and dimensions of the cell occupied by one unit. This measurement corresponds to the determination of the spacing between two lines in the diffraction grating.

A further step which the X-rays can take is the determination of the relative intensities of the various orders of the diffracted rays. This information leads, if it can be interpreted, to a knowledge of the mutual arrangement of the molecules in the crystal. The operation which is always carried out in the case of X-rays so far as present experience will allow, is analogous to a determination of the form of the grooves of the diffraction grating by measuring the relative intensities of the various orders of diffracted light. Two stages may be distinguished in this process. One of them comparatively easy; the other of difficulty, and sometimes of very great difficulty.

The outer form of a crystal depends upon the internal arrangement of the atoms and molecules, and the group employed by Nature is in general the chemical molecule. It is possible to distinguish thirty-two different classes, each characterized by its own special form. Mathematical crystallography has carried the possibilities of classification further than the outward form can reveal. Taking any group of atoms, it has been shown that in each class having its special external characteristics, there are several ways of arranging the groups so as to give the same outward appearance. These different methods of arrangement are nearly always distinguishable from one another by their action on the X-rays. There are in all 230 of them. An early result of the X-ray analysis is, therefore, the determination of the special arrangement of the molecules within the crystal.

The next stage, the more difficult one, is a determination of the full linear and angular relations between the position of the molecules and the atoms within the molecules. The aids to this determination are relative measurements of intensities of diffraction as revealed by X-rays, to which must be added all that may be known of the chemical, physical and mechanical characteristics of the atoms and the molecules. In some simple cases the analysis may be said to be already complete, but in the hundreds of thousands of known crystals there is, of course, an immense field still to be covered.

Models can be constructed, based on the results already obtained, which illustrate the structure of many crystalline substances.

Interpretation of Crystal Structure

It will now be convenient to refer to some of the principles of structure which X-ray analysis has already revealed. It is clear that such principles are worthy of careful investigation, for they may throw light on chemical and physical actions and also help in further determinations of crystal structure. There is in the first place a broad division into different methods of combination between the atoms. Three types can be recognized. The first of these is illustrated by such crystal structures as rock-salt, fluorspar, calcite and so forth. The structure depends mainly upon a group formed in obedience to laws of electrostatic action. If, for example, we take the case of rock-salt, the chlorine atom has taken away from the sodium atom one electron which it has incorporated into its own structure. According to the modern views of atomic constitution the chlorine atom, which has seven electrons in its outermost electron shell, is eager to complete the shell—completion implying the presence of eight electrons in that shell. Neon, which has eight, already seems to show by its unwillingness to enter into chemical combination, in other words, by its unwillingness to give, take or share electrons, that there is something which makes the eight a satisfactory and complete number. Sodium has the completed outer shell of eight and one which is the beginning of a new shell external to the old. It appears to have a poor hold on this odd electron, so that chlorine easily removes it. In consequence the chlorine becomes a negatively charged body, and the sodium a positively charged body.

Each positive surrounds itself with as many negatives as possible, and each negative with as many positives as possible. The cubic structure of rock-salt is obtained in this way, each atom having six neighbors of opposite sign. In fluorspar, where the calcium atom has been robbed of its two extra electrons by two fluorine atoms, each of which takes one, Nature has found a structure in which the positively charged calcium is surrounded by eight negative fluorines, and the fluorines by four calciums. In Iceland spar the same principle governs the structure. Each calcium atom is surrounded by six CO_3 groups, and each CO_3 group by six calciums. The structure is not, however, so regular as a rock-salt because the CO_3 group is not spherical in form and characteristic. There is a large class of crystals built on the same plan. There is a certain indefiniteness about the molecule because a positive can be associated with any one of the six negative neighbors which it possesses. It is

notable that, in the calcite, the CO_3 group must have such a degree of symmetry as is represented by the properties of an equilateral triangle. If it is turned round 120° in its own plane, it has the same appearance as before. This implies that the three oxygen atoms are all alike in their relations to one another, and to the other atoms of the crystal. However, the crystal may come to pieces under chemical action. A compound of calcium atoms and CO_3 groups is not a mixture of CO_2 and CaO. It is supposed that the carbon atom is stripped of all the four electrons which it normally possesses in its outer shell. The calcium atom loses also the two electrons which it has outside its completed shell. Each of the oxygen atoms takes two of the six electrons thus set free. Consequently each carbon atom has a quadruple positive charge, each oxygen a double negative charge, and the calcium a double positive charge.

A second method of combination is to be found in the diamond. The carbon atoms of which alone it consists are so arranged that each carbon has four neighbors arranged about it in tetrahedral fashion. Each shares two electrons with each of its neighbors, and in this way covers itself with the desired shell of eight electrons. It appears that the sharing produces a very strong bonding; the diamond is the hardest of known substances.

In graphite there are sheets of atoms tied tightly to one another by the sharing bonds of the diamond, but these sheets are separated from one another by a considerable interval. In this way may be explained the slipperiness of graphite and its usefulness as a lubricant because in the first place the layers slip on one another easily, the bonds that tie them together being weak, and in the second place, the atoms in each layer hold tightly together. There are indications that these tight bonds are much less affected by temperature than bonds of a looser type. For example, the coefficient of expansion with heat of the diamond is far less than the average expansion of graphite, but the expansion of graphite takes place almost entirely through increased separation of the layers.

Organic Crystals

There is yet a third method of combination, in general much weaker than the other two. When molecules, as in organic crystals, are built together into a structure, the forces that bind together molecule and molecule may be comparatively weak. The separate molecules are not positive or negative to each other, nor do they share electrons, but no doubt there are stray fields, perhaps electric, perhaps magnetic, at different points on their surfaces which cause the molecules to be joined on to one another like the girders of an iron bridge. The crystal structure is very empty; it is like lace-

work in space. We get the first hint of this likeness in the diamond where the empty spaces are big enough to accommodate as many more carbon atoms as a diamond already contains. The root principle seems to be that the carbon atom, when sharing electrons, gathers round it four neighbors more or less at the corners of a tetrahedron. If these points of attachment are spaced, so to speak, over the surface of the carbon atom, it is easy to understand how these open structures can be formed.

In the diamond crystal the structure shows two types of arrangement which form the basis of two of the great groups of organic substances. There is in the first place the hexagonal ring, which appears to be capable of separate existence in unchanged form and dimension, and when fringed with various atoms of radicles to form the innumerable members of the aromatic series. The double and treble rings are found in naphthalene and anthracene respectively, and the structure of these crystals, as revealed by X-rays, shows that the ring is the same in all respects as in the diamond. There is also to be found in the diamond an arrangement of long chains, which may have any length of carbon atoms. These chains, when fringed along their length by hydrogen atoms and finished off at each end with various groups of atoms, such as the methyl group (CH_3), the carboxyl group ($COOH$), the hydroxyl group (OH), and so on, form the well-known chain compounds of organic chemistry. Measurements of the lengths of these chains have recently been made very exactly by the X-ray methods in a number of cases, and it appears that the arrangement is, as the models show, just the same as is found in the diamond. The essential feature is that any two carbon atoms are joined on to a third at points on the surface of the latter, which are tetrahedral points.

Structure of Metals

The application of the X-rays to the crystal analysis of metals has shown very remarkable results, which will probably receive great extension in the future. Many of the metals—aluminium, silver, copper and gold, for example—are of a structure which implies the simplest form of close packing of spherical atoms. These plates are those in which the packing is most dense. A mass of crystals is stronger than a single crystal because the planes of weakness lie in all directions. An admixture of a certain number of foreign atoms causes a distortion of the structure, which diminishes the possibility of slip, and thus the hardening effect of an alloid is explained.

In the case of steel it seems likely that the carbon atoms do not replace iron atoms, as for example, tin atoms replace those of copper

in the formation of bronze; they appear to fit into the interstices of the structure. The structural nature of the various crystals which form in alloys, as for example, cementite in steel and intermetallic compounds in other alloys, have also been the subject of investigation.

Among the many other developments to which X-ray analysis is leading, one more may be mentioned. It now seems possible to calculate, from a knowledge of the structure and of the atoms which compose it, the effects upon electro-magnetic waves, such as those of light on their way through the crystal. A beginning in this respect has been made with the measurements of the reflection indices of calcite and aragonite.

ELECTRICITY AND MATTER[1]

By SIR ERNEST RUTHERFORD, F.R.S.

The Electron

The discovery by Sir J. J. Thomson in 1897 of the individual existence of the negative electron of small mass, and the proof that it was a component of all the atoms of matter, was an event of extraordinary significance to science, not only for the light which it threw on the nature of electricity, but also for the promise it gave of methods of direct attack on the problem of the structure of the atom. This discovery of the electron, coupled with the recognition of the atomic nature of electricity, has created a veritable revolution in our ideas of atoms.

It was soon recognized that the negative electron of small mass was an actual disembodied atom of electricity, and that its apparent mass was electrical in origin. Sir J. J. Thomson had shown so early as 1881 that a charged body in motion behaved as if it had an additional electric mass due to its motion. The moving charge generates a magnetic field in the space surrounding it, resulting in an increase of energy of the moving system which is equivalent to the effect produced by an increase of the mass of the body.

Since there must always be electric mass associated with the movement of electric charges, it is natural to suppose that the mass of the electron is entirely electrical in origin, and no advantage is gained by supposing that any other type of mass exists. If the atom is a purely electrical structure, the mass of the atom itself must be due to the resultant of the electric mass of the charged particles

[1] Abstracted from the Kelvin Lecture delivered before the Institution of Electrical Engineers on May 18, 1922.

which make up its structure. As only a small fraction of the mass of an atom can be ascribed to the negative electrons contained in it, the main part is due to the positively charged units of its structure.

THE PROTON

One of the main difficulties in our attack on the question of atomic constitution has lain in the uncertainty of the nature of positive electricity. The evidence as a whole supports the idea that the nucleus of the hydrogen atom, *i.e.*, a positively charged atom of hydrogen, is the positive electron. No evidence has been obtained of the existence of a positively charged unit of mass less than that of the hydrogen nucleus, either in vacuum tubes or in the transformation of the radio-active atoms, where the processes occurring are very fundamental in character.

It might *a priori* have been anticipated that the positive electron should be the counterpart of the negative electron and have the same small mass. There is, however, not the slightest evidence of the existence of such a counterpart. On the views outlined, the positive and negative electrons both consist of the fundamental unit of charge, but the mass of the positive is about 1,800 times that of the negative. This difference in the mass of the two electrons seems a fundamental fact of Nature, and, indeed, is essential for the existence of atoms as we know them. The unsymmetrical distribution of positive and negative electricity that is characteristic of all atoms is a consequence of this wide difference in the mass of the ultimate electrons which compose their structure. No explanation can be offered at the moment why such a difference should exist between positive and negative electricity.

Since it may be argued that a positive unit of electricity associated with a much smaller mass than the hydrogen nucleus may yet be discovered, it may be desirable not to prejudge the question by calling the hydrogen nucleus the positive electron. For this reason, and also for brevity, it has been proposed that the name "proton" should be given to the unit of positive electricity associated in the free state with a mass about that of the hydrogen nucleus. In the following, the term "electron" will be applied only to the well-known negative unit of electricity of small mass.

On the classical electrical theory, the mass of the electron can be accounted for by supposing that the negative electricity is distributed on a spherical surface of radius about 1×10^{-13} cm. This is merely an estimate, but probably gives the right order of magnitude of the dimensions.

The greater mass of the proton is to be explained by supposing that the distribution of electricity is much more concentrated for

the proton than for the electron. Supposing the shape spherical, the radius of the proton should be only 1/1800 of that of the electron. If this be so, the proton has the smallest dimensions of any particle known to us. It is admittedly very difficult to give any convincing proof in support of this contention, but at the same time there is no evidence against it.

Structure of the Atom

Progress in the last twenty years of our ideas on the structure of atoms has depended mainly on a clearer understanding of the relative part played by positive and negative electricity in atomic structure. It is now generally accepted that the atom is an electrical system and that the atoms of all the elements have a similar type of structure.

The nuclear theory of atomic constitution has been found to be of extraordinary value in offering an explanation of the fundamental facts that have come to light, and is now generally employed in all detailed theories of atomic constitution. At the center of each atom is a massive positively charged nucleus of dimensions minute compared with the diameter of the atom. This nucleus is surrounded by distribution of negative electrons which extend to a distance, and occupy rather than fill a region of diameter about 2×10^{-8} cm. Apart from the mass of the atom, which resides mainly in the nucleus, the number and distribution of the outer electrons, on which the ordinary physical and chemical properties of the atom depend, are controlled by the magnitude of the nuclear charge. The position and motions of the external electrons are only slightly affected by the mass of the nucleus.

According to this view of the atom, the problem of its constitution naturally falls into two parts—first, the distribution and mode of motion of the outer electrons, and secondly, the structure of the nucleus and the magnitude of the resultant positive charge carried by it. In a neutral atom the number of external electrons is obviously equal in number to the units of positive (resultant) charge on the nucleus.

The general conception of the nuclear atom arose from the need of explanation of the very large deflexions experienced by swift particles thrown off by radio-active substances, known as α- and β-particles, in passing through the atoms of matter. A study of the number of α-particles scattered through different angles showed that there must be a very intense electric field within the atom, and gave us a method of estimating the magnitude of the charge on the nucleus. Similarly, the scattering of X-rays by the outer electrons provided us with an estimate of the number of these electrons in the

atom, and the two methods gave concordant values. The next great advance we owe to the experiments of Moseley on the X-ray spectra of the elements. He showed that his experiments received a simple explanation if the nuclear charge varied by one unit in passing from one atom to the next. In addition, it was deduced that the actual magnitude of the nuclear charge of an atom in fundamental units is equal to the atomic or ordinal number when the elements were arranged in order of increasing atomic weight. On this view, the nuclear charge of hydrogen is 1, of helium 2, lithium 3, and so on up to the heaviest element uranium, of charge 92. It has been found that between these limits, with few exceptions, all nuclear charges are represented by known elements.

This relation, found by Moseley, between the atoms of the elements, is of unexpected simplicity and of extraordinary interest. The properties of an atom are defined by a whole number which varies by unity in passing from one atom to the next. This *atomic number* represents not only the ordinal number of the elements, but also the magnitude of the charge of the nucleus and the number of outer electrons. The atomic weight of an element is not nearly so fundamental a property of the atom as its nuclear charge, for its weight depends upon the inner structure of the nucleus, which may be different for atoms of the same nuclear charge.

The Nucleus of the Atom

The most definite information we have of the structure of the nucleus of an atom has been obtained from a study of the modes of disintegration of the radio-active atoms. In the great majority of cases the atom breaks up with the expulsion of a single α-particle which represents the doubly charged nucleus of the helium atom; in other cases a swift β-ray or electron is liberated. There can be no doubt that these particles are liberated from the nuclei of the radio-active atoms. This is clearly shown by the variation of the atomic numbers (the figures enclosed by the circles) of the successive elements in the long series of transformations of uranium and thorium (see Fig. 1). The expulsion of an α-particle lowers the nuclear *charge* of the atom by two units and its *mass* by four, while the expulsion of an electron raises its charge by one. On this simple basis we can at once deduce the atomic number and, consequently, the general chemical properties of the long series of radio-active elements. In this way we can understand at once the appearance in the radio-active series of isotopes, *i.e.,* elements of the same nuclear charge but different atomic masses.

The existence of isotopic elements was first brought to light from

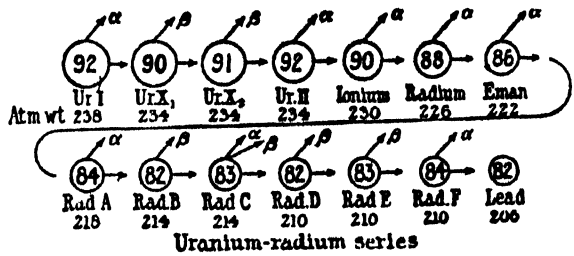


FIG. 1

a study of the radio-active elements. For example, radium-*B*, radium-*D* and the end product, uranium-lead, are isotopes of lead of nuclear charge 82, but of masses 214, 210 and 206 respectively. As regards ordinary chemical and physical properties, they are indistinguishable from one another, differing only in properties that depend on the nucleus, namely, atomic mass and radio-activity. For example, radium-*B* and radium-*D* both emit β-rays, but with different velocities, while their average life is widely different. Uranium-lead, on the other hand, is non-radio-active. Many similar examples can be taken from the thorium and actinium series of elements. These illustrations show clearly that elements may have almost identical physical and chemical properties, and yet differ markedly in the mass and structure of their nuclei.

From the radio-active evidence, it seems clear that the nuclear structure contains both helium nuclei and electrons. In the uranium-radium series of transformations, eight helium nuclei are emitted and six electrons, and it is natural to suppose that the helium nuclei and electrons that are ejected act as units of the nuclear structure. It is clear from these results that the nuclear charge of an element is the excess of the positive charges in the nucleus over the negative. It is a striking fact that no protons (H nuclei) appear to be emitted in any of the radio-active transformations, but only helium nuclei and electrons.

Some very definite and important information on the structure of nuclei has been obtained by Aston in his experiments to show the existence of isotopes in the ordinary stable elements by the well-known positive-ray method. He found that a number of the elements were simple and contained no isotopes. Examples of such "pure" elements are carbon, nitrogen, oxygen and fluorine. It is significant that the atomic weights of these elements are nearly whole numbers in terms of $O = 16$; on the other hand, elements such as neon, chlorine, krypton and many others consisted of mixtures of two or more isotopes of different atomic masses. Aston

found that within the limit of error—about 1 in 1,000—the atomic weights of these isotopes were whole numbers on the oxygen scale. This is a very important result, and suggests that the nuclei of elements are built up by the addition of protons, of mass nearly one, in the nuclear combination.

Disintegration of Elements

There seems to be no doubt that the nucleus of an atom is held together by very powerful forces, and that we can only hope to effect its disintegration by very concentrated sources of energy applied directly to the nucleus. The most concentrated source of energy known to us is the swift α-particle expelled from radium or thorium. It is liberated with a velocity of 10,000 miles per second, and has so much energy that it produces an easily visible flash on striking a zinc sulphide crystal. Its speed is twenty thousand times greater than that of a swift rifle bullet, and, mass for mass, its energy of motion is four hundred million times greater than that of the bullet.

A stream of α-particles is therefore made to bombard the atoms of the material under examination. On account of the minute size of the nucleus, we can expect an α-particle only occasionally to get near enough to the nucleus to effect its disintegration, and this method should be more likely to succeed with a light atom, in which the repulsive force of the nucleus would not be so great as that of a heavy atom with high nuclear charge.

The first observation indicating the disruption of the nitrogen nucleus was made some years ago. When α-particles were passed through oxygen or carbon-dioxide, a few particles of long range were observed. These appeared to be H-nuclei set free from hydrogen in the radio-active source, which, on account of their small mass, would be expected to have a greater range than the α-particles liberating them. When, however, dry air or nitrogen is submitted to such a bombardment, the number of long-range particles is three or four times as numerous, and they have a greater average range. These behaved in all respects as H-nuclei, and it was concluded that they arose from disruption of the nitrogen nuclei.

Using improved apparatus, it was possible to show that similar long-range particles were liberated from boron, fluorine, sodium, aluminium and phosphorus. The range of the particles is in all cases greater than that of the H-particles liberated from free H atoms under similar conditions. For example, using radium-*C* as a source of X-rays, the range of the H-nuclei is about 28 cm. Under similar conditions, the range of the particles from nitrogen is 40

cm., while the range of particles from aluminium is as much as 90 cm.

It is thus natural to conclude that "protons" have been ejected from the nuclei of certain light elements by the action of the α-particles. It is significant that no protons are liberated from carbon (12) and oxygen (16), the atomic weights of which are given by $4n$, where n is a whole number. Protons are only observed from elements of which the atomic weights are expressed by $4n + a$, where a is 2 or 3. These results suggest that the elements are, in the main, built up of helium nuclei of mass 4, and protons. The α-particle is unable to liberate a proton from elements like carbon and oxygen which are built up entirely of helium nuclei as secondary units, probably because the helium nucleus is too stable to be broken up by the swiftest α-particle available. It should be borne in mind, however, that this disintegration phenomenon effected by α-particles is on an exceedingly minute scale. Only two protons are liberated from aluminium for a million α-particles traversing it.

The Architecture of Atoms

From the radio-active evidence, we know that the nuclei of heavy atoms are built up, in part at least, of helium nuclei and electrons, while it also seems clear that the proton can be released from the nuclei of certain light atoms. It is, however, very natural to suppose that the helium nucleus which carries two positive charges is a secondary building unit, composed of a close combination of protons and electrons, namely, 4 protons and 2 electrons.

From the point of view of simplicity, such a conception has much in its favor, although it seems at the moment impossible to prove its correctness. If, however, we take this structure of the helium nucleus as a working hypothesis, certain very important consequences follow.

Taking the mass of the oxygen atom as 16 (the standard which is usually adopted in atomic weight determinations), the helium atom has a mass very nearly 4·000, while the hydrogen atom has a mass 1·0077. The mass of the helium atom is thus considerably less than that of four free H-nuclei. Disregarding the small mass of electrons, in the formation of 1 gram of helium from hydrogen there would be a loss of mass of 7·7 milligrams.

It is now generally accepted that if the formation of a complex system is accompanied by the radiation of energy, a reduction of its mass occurs, which can be calculated. In the formation of 1 gram of helium from hydrogen an enormous amount of energy is set free; the energy radiated in forming one single atom of helium is equivalent to the energy carried by three or four swift α-particles from

radium. On this view we can at once understand why it should be impossible to break up the helium nucleus by a collision with an α-particle. In fact, the helium atom should be by far the most stable of all the complex atoms.

Most workers on the problem of atomic constitution take as a working hypothesis that the atoms of matter are purely electrical structures, and that ultimately it is hoped to explain all the properties of atoms as a result of certain combinations of the two fundamental units of positive and negative electricity, the proton and electron. Some of the more successful methods of attack that have been made on this most difficult of problems have been indicated. During recent years unexpectedly rapid advances have been made in our knowledge, but we have only made a beginning in the attack on a very great and intricate problem.

ATOMS AND ISOTOPES[1]

By Dr. F. W. ASTON, F.R.S.

THE SIZE OF ATOMS

That matter is discontinuous and consists of discrete particles is by no means obvious to the senses. The surfaces of clean liquids, even under the most powerful microscope, appear perfectly smooth, coherent and continuous. The merest trace of a soluble dye will color millions of times its volume of water. It is not surprising therefore that, in the past, there have arisen schools who believed that matter was quite continuous and infinitely divisible.

The upholders of this view said that if you took a piece of material, lead, for instance, and went on cutting it into smaller and smaller fragments with a sufficiently sharp knife, you could go on indefinitely. The opposing school argued that at some stage in the operations either the act of section would become impossible, or the result would be lead no longer.

The accuracy of modern knowledge is such that we can carry out, indirectly at least, the experiment suggested by the old philosophers right up to the stage when the second school is proved correct, and the ultimate atom of lead is reached. For convenience, we can start with a standard decimeter cube of lead weighing 11.37 kilograms, and the operation of section will consist of three cuts at right angles to each other, dividing the original cube into eight similar bodies, each of half the linear dimensions and one eighth the weight.

[1] Abstracted from lecture delivered before the Franklin Institute, Philadelphia, on March 6–10, 1922.

Thus the first cube will have 5 cm. sides and weigh 1 42 kilograms, the second will weigh 178 gm., the fourth 2 78 gm., and so on. Diminution in the series is very rapid, and the result of the ninth operation is a quantity of lead just weighable on the ordinary chemical balance. The last operation possible, without breaking up the lead atom, is the twenty-eighth. The twenty-sixth cube contains 64 atoms, the size, distance apart and general arrangement of which can be represented with considerable accuracy, thanks to the exact knowledge derived from research on X-rays and specific heats.

The following table shows at what stages certain analytical methods break down. The great superiority of the microscope is a noteworthy point.

Cube.	Side in cm.	Mass in gm.	Limiting Analytical Method.
9	0 0195	$8\ 5 \times 10^{-5}$	Ordinary Chemical Balance.
14	$6\,1 \times 10^{-4}$	2.58×10^{-9}	Quartz Micro-balance.
15	$3\,05 \times 10^{-4}$	$3\,22 \times 10^{-10}$	Spectrum Analysis (Na lines).
18	$3\,8 \times 10^{-5}$	$6\,25 \times 10^{-13}$	Ordinary Microscope.
24	$6\,0 \times 10^{-7}$	$2\,38 \times 10^{-18}$	Ultra-Microscope.
28	$3\,7 \times 10^{-8}$	$5\,15 \times 10^{-22}$	
Atom	$3\,0 \times 10^{-8}$	$3\,44 \times 10^{-22}$	Radioactivity.

Just as any vivid notion of the size of the cubes passes out of our power at about the twelfth—the limiting size of a dark object visible to the unaided eye—so when one considers the figures expressing the number of atoms in any ordinary mass of material, the mind is staggered by their immensity. Thus if we slice the original decimeter cube into square plates one atom thick, the area of these plates will total one and one quarter square miles. If we cut these plates into strings of atoms spaced apart as they are in the solid, these decimeter strings put end-to-end will reach 6.3 million million miles, the distance light will travel in a year, a quarter of the distance to the nearest fixed star. If the atoms are spaced but one millimeter apart, the string will be three and a half million times longer yet, spanning the whole universe.

From the above statements it would, at first sight, appear absurd to hope to obtain effects from single atoms, yet this can now be done in several ways, and indeed it is largely due to the results of such experiments that the figures can be stated with so much confidence. Detection of an individual is only feasible in the case of an atom moving with an enormous velocity, when its energy is quite appreciable, although its mass is so minute. The charged helium atom shot out by radioactive substances in the form of an α-ray possesses so much energy that the splash of light caused by its impact against a fluorescent screen can be visibly detected; the ionization caused by its passage through a suitable gas can be measured on a sensitive

electrometer, and, in the beautiful experiments of C. T. R. Wilson, its path in air can be both seen and photographed by means of the condensation of water drops upon the atomic wreckage it leaves behind it.

Discovery of Isotopes

In the first complete atomic theory put forward by Dalton in 1803 one of the postulates states that: "Atoms of the same element are similar to one another and equal in weight." Of course, if we take this as a definition of the word "element" it becomes a truism, but, on the other hand, what Dalton probably meant by an element, and what we understand by the word to-day, is a substance such as hydrogen, oxygen, chlorine, or lead, which has unique chemical properties, and can not be resolved into more elementary constituents by any known chemical process. For many of the well-known elements Dalton's postulate still appears to be strictly true, but for others, probably the majority, it needs some modification.

The idea that atoms of the same element are all identical in weight could not be challenged by ordinary chemical methods, for the atoms are by definition chemically identical, and numerical ratios were only to be obtained in such methods by the use of quantities of the element containing countless myriads of atoms.

There are two ways by which the identity of the weights of the atoms forming an element can be tested. One is by the direct comparison of the weights of individual atoms; the other is by obtaining samples of the element from different sources or by different processes, samples which, although perfectly pure, do not give the same chemical atomic weight. It was by the second and less direct of these methods that it was first shown that substances could exist which, though chemically identical, had different atomic weights. To these the name "isotopes" was applied by Prof. Soddy.

Measurement of Masses of Individual Atoms

In the absence of the special radioactive evidence which can be used in special cases such as that of lead, the presence of isotopes among the inactive elements can only be detected by the direct measurement of the masses of individual atoms. This can be done by the analysis of positive rays.

The condition for the development of these rays is briefly ionization at low pressure in a strong electric field. Ionization, which may be due to collisions or radiation, means in its simplest case the detachment of one electron from a neutral atom. The two resulting fragments carry charges of electricity of equal quantity

but of opposite sign. The negatively-charged one is the electron, the atomic unit of negative electricity itself, and is the same whatever the atom ionized. It is extremely light, and therefore in the strong electric field rapidly attains a high velocity and becomes a cathode ray. The remaining fragment is clearly dependent on the nature of the atom ionized. It is immensely more massive than the electron, for the mass of the lightest atom, that of hydrogen, is about 1,800 times that of the electron, and so will attain a much lower velocity under the action of the electric field. However, if the field is strong and the pressure so low that it does not collide with other atoms too frequently, it will ultimately attain a high speed in a direction opposite to that of the detached electron, and become a "positive ray."

Positive rays can be formed from molecules as well as atoms; so any measurement of their mass will give us direct information as to the masses of atoms of elements and molecules of compounds; moreover, this information will refer to the atoms or molecules *individually,* not, as in chemistry, to the mean of an immense aggregate. It is on this account that the accurate analysis of positive rays is of such importance.

In order to investigate and analyze them it is necessary to obtain intense beams of the rays. This can be done in several ways. The one most generally available is by the use of the discharge in gases at low pressure.

The comparatively dimly lit space in a discharge tube between the cathode and the bright "negative glow" is named after its discoverer the "Crookes' dark space." Ionization is going on at all points throughout the dark space, and it reaches a very high intensity in the negative glow. This ionization is probably caused for the most part by electrons liberated from the surface of the cathode (cathode rays). These, when they reach a speed sufficient to ionize by collision, liberate more free electrons, which in their turn become ionizing agents, so that the intensity of ionization from this cause will tend to increase as we move away from the cathode. The liberation of the original electrons from the surface of the cathode is generally regarded as due to the impact of the positive ions (positive rays) generated in the negative glow and the dark space. In addition to cathode ray ionization the positive rays travelling towards the cathode themselves are capable of ionizing the gas, and radiation may also play an important part in the same process.

The surface of the cathode will therefore be under a continuous hail of positively charged particles. Their masses may be expected to vary from that of the lightest atom to that of the heaviest mol-

ecule capable of existence in the discharge tube, and their energies from an indefinitely small value to a maximum expressed by the product of the charge they carry multiplied by the total potential applied to the electrodes. If the cathode be pierced, the rays pass through the aperture and form a stream, heterogeneous both in mass and velocity, which can be subjected to examination and analysis.

Analysis of Positive Rays

In Sir J. J. Thomson's "parabola" method of analysis of positive rays, the particles, after reaching the surface of the cathode, enter a long and very fine metal tube. By this means a narrow beam of rays is produced which is passed through electric and magnetic fields, causing deflexions at right angles to each other, and finally falls upon a screen of fluorescent material or a photographic plate. It can then be shown that if the mass of any particle is m and its charge e, when both fields are on together, the locus of impact of all particles of the same e/m, but varying velocity, will be a parabola Since e must be the electronic charge, or a simple multiple of it, measurement of the relative positions of the parabolas on the plate enables us to calculate the relative masses of the particles producing them—that is, the masses of the individual atoms. The fact that the streaks were definite, sharp parabolas, and not mere blurs, constituted the first direct proof that atoms of the same element were, even approximately, of equal mass.

Many gases were examined by this method, and some remarkable compounds, such as H_3, discovered by its means. When in 1912 neon was introduced into the discharge tube, it was observed to exhibit an interesting peculiarity. Whereas all elements previously examined gave single, or apparently single, parabolas, that given by neon was definitely double. The brighter curve corresponded roughly to an atomic weight of 20, the fainter companion to one of 22, the atomic weight of neon being 20.20. Sir J. J. Thomson was of the opinion that line 22 could not be attributed to any compound, but that it represented a hitherto unknown elementary constituent of neon. This agreed very well with the idea of isotopes which had just been promulgated, so that it was of great importance to investigate the point as fully as possible.

The first line of attack was an attempt at separation by fractional distillation over charcoal cooled with liquid air, but even after many thousands of operations the result was entirely negative. The second method employed was that of fractional diffusion through pipeclay, which after months of arduous work gave a small,

but definite positive indication of separation. A difference of about 0.7 per cent between the densities of the heaviest and lightest fractions was obtained. It therefore seemed probable that neon was a mixture of isotopes.

The Mass-Spectrograph

By the time the work on the subject was resumed in 1919, the existence of isotopes among the products of radio-activity had been put beyond all reasonable doubt by the work on the atomic weight of lead. This fact automatically increased both the value of the evidence of the complex nature of neon and the urgency of its definite confirmation. It was realized that separation could only be very partial at the best, and that the most satisfactory proof would be afforded by measurements of atomic weight by the method of positive rays. These would have to be so accurate as to prove beyond dispute that the accepted atomic weight lay between the real atomic weights of the constituents, but corresponded with neither of them.

The parabola method of analysis was not sufficient for this, but the required accuracy was achieved by a new arrangement. The rays, after arriving at the cathode face, are made to pass through two very narrow parallel slits of special construction, and the resulting thin ribbon of rays is spread out into an electric spectrum by means of parallel charged plates. After emerging from the electric field, a group of the rays is selected by means of a diaphragm, and made to pass between the parallel poles of a magnet. By this means the rays are brought to a focus, though spread out spectrum fashion, on a photographic plate.

Thus the instrument is a close analogue of the ordinary spectrograph, and gives a "spectrum," which, however, depends upon mass; it was therefore called a "mass-spectrograph" and the spectrum it produces a "mass-spectrum."

The measurements of mass thus made are not absolute, but relative to lines which correspond to known masses. Such lines due to hydrogen, carbon, oxygen and their compounds are generally present as impurities or purposely added, for pure gases are not suitable for the smooth working of the discharge tube.

It must be remembered that the ratio of mass to charge is the real quantity measured by the position of the lines. Many of the particles are capable of carrying more than one charge. A particle carrying two charges will appear as having half its real mass, one carrying three charges as if its mass was one third, and so on. Lines due to these are called lines of the second and third order.

Lines of high order are particularly valuable in extending the reference scale.

When neon was introduced into the apparatus, four new lines made their appearance at 10, 11, 20 and 22. The first pair are second order lines and are fainter than the other two, and a series of consistent measurements showed that to within about one part in a thousand the atomic weights of the isotopes composing neon are 20 and 22 respectively. Ten per cent. of the latter would bring the mean atomic weight to the accepted value of 20.20, and the relative intensity of the lines agrees well with this proportion. The isotopic constitution of neon seems therefore settled beyond all doubt.

The element chlorine was naturally the next to be analyzed, and the explanation of its fractional atomic weight was obvious from the first plate taken. Its mass spectrum is characterized by four strong first order lines at 35, 36, 37, 38, with fainter ones at 39, 40. There is no sign whatever of any line at 35 46. The simplest explanation of the group is to suppose that the lines 35 and 37 are due to the isotopic chlorines and lines 36 and 38 to their corresponding hydrochloric acids. The elementary nature of lines 35 and 37 is also indicated by the second order lines at 17.5, 18.5, and also, when phosgene was used, by the appearance of lines at 63, 65, due to $COCl^{35}$ and $COCl^{37}$.

Quite recently it has been found possible to obtain the spectrum of negatively-charged rays. These rays are formed by a normal positively-charged ray picking up two electrons. On the negative spectrum of chlorine only two lines, 35 and 37, can be seen, so that the lines at 36 and 38 can not be due to isotopes of the element. These results go to show that chlorine is a complex element, and that its principal isotopes are of atomic weight 35 and 37. There may be, in addition, a small proportion of a third of weight, 39, but this is doubtful.

The method of positive ray analysis having been applied so successfully to neon and chlorine, other elements were quickly submitted to its searching investigation. Positive rays of the metallic elements can not, in general, be obtained by the discharge tube method, but require special devices. Thus the isotopic nature of lithium was first demonstrated by the use of anode rays derived from anodes containing salts of that metal, and since then, all the other alkali metals have been successfully analyzed.

A powerful and ingenious method of generating positive rays of metallic elements has been used with great success by Dempster at Chicago. He employs the element in the metallic state, and

ionizes its vapor by means of a subsidiary beam of cathode rays. The ions so produced are allowed to fall through a definite potential, and, being therefore of constant energy, can be analyzed by the use of a magnetic field alone. By this arrangement Dempster discovered the three isotopes of magnesium, and has since analyzed other metals. Since the majority of the elements not yet investigated are metals, Dempster's method is likely to yield enormously important results in the future. A complete list of the isotopes of the non-radio-active elements so far discovered is given in the table.

TABLE OF ELEMENTS AND ISOTOPES

Element	Atomic number	Atomic weight	Minimum number of isotopes	Masses of isotopes in order of intensity
H	1	1 008	1	1 008
He	2	3.99	1	4
Li	3	6.94	2	7, 6
Be	4	9 1	1	9
B	5	10.9	2	11, 10
C	6	12.00	1	12
N	7	14.01	1	14
O	8	16 00	1	16
F	9	19.00	1	19
Ne	10	20.20	2	20, 22
Na	11	23.00	1	23
Mg	12	24.32	3	24, 25, 26
Al	13	26.96	1	27
Si	14	28.3	2	28, 29, (30)
P	15	31.04	1	31
S	16	32.06	1	32
Cl	17	35.46	2	35, 37
A	18	39.88	2	40, 36
K	19	39.10	2	39, 41
Ca	20	40.07	(2)	40, 44
Sc	21	45.1	1	45
Ti	22	48.1	1	48
V	23	51.0	1	51
Cr	24	52.0	1	52
Mn	25	54.93	1	55
Fe	26	55.84	(1)	56, (54) ?
Co	27	58.97	1	59
Ni	28	58.68	2	58, 60
Cu	29	63.57	2	63, 65
Zn	30	65.37	(4)	64, 66, 68, 70
Ga	31	69.72	2	69, 71
Ge	32	72.5	3	74, 72, 70
As	33	74.96	1	75
Se	34	79.2	6	80, 78, 76, 82, 77, 74
Br	35	79.92	2	79, 81
Kr	36	82.92	6	84, 86, 82, 83, 80, 78
Rb	37	85.45	2	85, 87
Sr	38	87.63	1	88
Y	39	88.9	1	89
Ag	47	107.88	2	107, 109
In	49	114.8	1	115
Sn	50	118.7	7 (8)	120, 118, 116, 124, 119, 117, 122, (121)
Sb	51	121.77	2	121, 123
I	53	126.92	1	127
X	54	130.2	7 (9)	129, 132, 131, 134, 136, 128, 130, (126), (124)
Cs	55	132.81	1	133
Hg	80	200.6	(6)	(197–200), 202, 204

(Numbers in parentheses are provisional only.)

SIGNIFICANCE OF THE DISCOVERY OF ISOTOPES

By far the most important general result of these investigations is that, with the exception of hydrogen, the weights of the atoms of all the elements measured, and therefore almost certainly of all elements, are whole numbers to the accuracy of experiment. With the mass-spectrograph, this accuracy is generally one part in a thousand. Of course, the error expressed in fractions of a unit in-

creases with the weight measured, but with the lighter elements the divergence from the whole number rule is extremely small.

This enables the most sweeping simplifications to be made in our ideas of mass. The original hypothesis of Prout, put forward in 1815, that all atoms were themselves built of atoms of "protyle," a hypothetical element which he tried to identify with hydrogen, is now re-established, with the modification that the primordial atoms are of two kinds: Protons and electrons, the atoms of positive and negative electricity. The atom, as conceived by Sir Ernest Rutherford, consists essentially of a positively-charged central nucleus around which are set planetary electrons at distances great compared with the dimensions of the nucleus itself.

The chemical properties of an element depend solely on its atomic number, which is the charge on its nucleus expressed in terms of the unit charge, e. A neutral atom of an element of atomic number N has a nucleus consisting of $K + N$ protons and K electrons and around this nucleus are set N electrons. The weight of an electron on the scale we are using is 0.0005, so that it may be neglected. The weight of this atom will therefore be $K + N$, so that if no restrictions are placed on the value of K, any number of isotopes are possible.

A statistical study of the results given above shows that the natural restrictions can be stated in the form of rules as follows:

(a) *In the Nucleus of an Atom There is Never Less Than One Electron to Every Two Protons.*—There is no known exception to this law. It is the expression of the fact that if an element has an atomic number N, the atomic weight of its lightest isotope can not be less than $2N$. True atomic weights corresponding exactly to $2N$ are known in the majority of the lighter elements up to A^{36}. Among the heavier elements the difference between the weight of the lightest isotope and the value $2N$ tends to increase with the atomic weight; in the cases of mercury it amounts to 37 units.

(b) *The Number of Isotopes of an Element and their Range of Atomic Weight Appear to Have Definite Limits.*—So far the element with the largest number of isotopes determined with certainty is krypton, with six, but the majority of complex elements have only two each. The maximum difference between the lightest and heaviest isotope of the same element so far determined is 8 units in the cases of krypton and xenon. The greatest proportional difference, calculated on the lighter weight, is recorded in the case of lithium, where it amounts to one sixth. It is about one tenth in the case of boron, neon, argon and krypton.

(c) *The Number of Electrons in the Nucleus Tends to be Even.*—This rule expresses the fact that in the majority of cases even

atomic number is associated with even atomic weight and odd with odd. If we consider the three groups of elements, the halogens, the inert gases and the alkali metals, this tendency is very strongly marked. Of the halogens—odd atomic numbers—all 6 (+ 1?) atomic weights are odd. Of the inert gases—even atomic numbers 13 (+ 2?) are even and 3 odd. Of the alkali metals—odd atomic numbers—7 are odd and 1 even. In the few known cases of elements of other groups the preponderance, though not so large, is still very marked and nitrogen is the only element yet discovered to consist entirely of atoms the nuclei of which contain an odd number of electrons.

In consequence of the whole number rule there is now no logical difficulty in regarding protons and electrons as the bricks out of which atoms have been constructed. An atom of atomic weight m is turned into one of atomic weight $m + 1$ by the addition of a proton plus an electron. If both enter the nucleus, the new element will be an isotope of the old one, for the nuclear charge has not been altered. On the other hand, if the proton alone enters the nucleus and the electron remains outside, an element of next higher atomic number will be formed. If both these new configurations are possible, they will represent elements of the same atomic weight, but with different chemical properties. Such elements are called "isobares" and are actually known.

The case of the element hydrogen is unique; its atom appears to consist of a single proton as nucleus with one planetary electron. It is the only atom in which the nucleus is not composed of a number of protons packed exceedingly closely together. Theory indicates that when such close packing takes place the effective mass will be reduced, so that when four protons are packed together with two electrons to form the helium nucleus, this will have a weight rather less than four times that of the hydrogen nucleus, which is actually the case. It has long been known that the chemical atomic weight of hydrogen was greater than one quarter of that of helium, but so long as fractional weights were general there was no particular need to explain this fact, nor could any definite conclusions be drawn from it. The results obtained by means of the mass-spectrograph remove all doubt on this point, and no matter whether the explanation is to be ascribed to packing or not, we may consider it absolutely certain that if hydrogen is transformed into helium a certain quantity of mass must be annihilated in the process.

The theory of relativity indicates that mass and energy are interchangeable and that in C.G.S. units a mass m at rest may be expressed as a quantity of energy mc^2, where c is the velocity of light. Even in the case of the smallest mass this energy is enor-

mous. If instead of considering single atoms we deal with quantities of matter in ordinary experience the figures for the energy become prodigious. Take the case of 1 gram-atom of hydrogen, that is to say, the quantity of hydrogen in 9 cc of water If this is entirely transformed into helium the energy liberated will be $0.0077 \times 9 \times 10^{20} = 6.93 \times 10^{18}$ ergs. Expressed in terms of heat this is $1\ 66 + 10^{11}$ calories or in terms of work, 200,000 kilowatt hours. The transmutation of the hydrogen from 1 pint of water would liberate sufficient energy to drive the *Mauretania* across the Atlantic and back at full speed.

Should the research worker of the future discover some means of releasing this energy in a form which could be employed, the human race will have at its command powers beyond the dreams of scientific fiction; but the remote possibility must always be considered that the energy once liberated will be completely uncontrollable and by its intense violence detonate all neighboring substances. In this event the whole of the hydrogen on the earth might be transformed at once and the success of the experiment published at large to the universe as a new star.

THE MATHEMATICIAN PASCAL, AS PHILOSOPHER AND SAINT
1623-1662[1]

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IT would be rather extravagant, I suppose, to speak of the many-sided Pascal. That saintly intellectual was not what such a description would be most likely to convey. Certainly Pascal was not a versatile man of the world. In several different fields of human interest, however, in mathematics and physics, in philosophy and religion, historians must take some account of him and biographers may not find his life an altogether simple one.

Of Pascal the mathematician I shall speak only generally and incidentally, and I shall call attention to certain characters or values in the mathematics and mathematicalism of his time; but his actual mathematics, even his very youthful precocity therein and his interesting cycloidal pursuit of Leibnitz and Newton, very properly I must leave to those who are more competent than I to discourse on such indoor sports. Of the scientist, too, widely applauded in his time, and since, for certain productive experiments in physics, I shall also not venture anything technically specific. In my present account of Pascal, philosopher and saint, I would say simply that his physical science and the peculiar freedom and purity of mind natural to mathematics and quite in contrast with the law or dogmatic theology or any institutional formalism, secular or ecclesiastical, must have been important influences not less on his spiritual than on his mental life. They must have been positive factors in the mental complex determining the real purport of his eventual emotional reactions to the thought and life, the philosophy and religious establishments of his time.

Those emotional reactions, as can hardly need saying, were the most expressive and characteristic phases of his life and of them chiefly, of Pascal's rather unconventional place in the history of

[1] This is one of four essays concerned more or less directly with the spiritual values or humanistic implications of the natural sciences and the scientific point of view. The three earlier papers have all been published in THE SCIENTIFIC MONTHLY, as follows: "Philosophy in the service of science," May, 1920; "The philosophy of Herbert Spencer," August, 1920, and "The time of day," November and December, 1923.

philosophy and of his spiritual character and saintliness, I am to speak. These I have found not easily appraised without regard to the scientist's candor towards nature and to the free rationalism, the broad mathematicalism, which were his and which were signs of his time. Mathematician, physicist, God-absorbed devotee, such was Pascal, all three; and, as I would show, not with any real inconsistency.

Both the science and the mathematics, as has to be said, he came finally to abandon, at least outwardly, and he actually passed by any constructively philosophical speculations which those disciplines had prompted in others and certainly might have prompted in him. Perhaps too suddenly he passed from the scientific and intellectual to the religious. Possibly a distinctly and technically philosophical period, tempering the transition, had been more normal and had made the later attitude or condition appear not so flatly opposed or negative to the earlier. Still even flat negation is often very different from what it seems. Seeming reactionary, it may be progressive. To say the least, although flat and sudden, it may be or become only a progressive movement of deepened insight and appreciation. Many a "no" has proved only a profounder "yes." Outward irrationalism, reason apparently quite supplanted by intuition or faith, has sometimes meant only superrationalism; rationalism, not destroyed, but accomplished.

II

To turn directly to the task of this essay, in what qualified sense, if in any sense at all, can Pascal be said to have been a philosopher? Technically, as has been remarked in so many words, he was not a philosopher. He was probably never really interested in working out a system of philosophy. He had the philosophical virtues—patience, sympathy, courage, endurance—but these hardly make him a philosopher professionally. Many of the historians fail to give him more than casual mention, while such as have space and time for him are quite likely to dwell on his antagonism to philosophy rather than on any possible contribution of a positive and constructive nature. Had he only carried out his avowed purpose of something in the manner of a systematic theology, in which he was to answer conclusively and comprehensively the opponents of the neo-Augustinian Jansenists, with whom he had associated himself, there might have been a good case for a more direct inclusion in the histories of philosophy than usually accorded him. In his time conspicuously all philosophy was still very consciously theological, theistically so or atheistically. But temperament as well as health, if the two be separable, made him disinclined to

any material constructions of reason. He could be a scientist for a time or a mathematician, but never really philosopher or theologian. The dominant systematic thought of his day, quite as theological as philosophical, he openly disparaged. So, contemporary with Descartes and Descartes' followers, Geulincx and Malebranche and Spinoza, all sharing with him the interest in mathematics and physical science and all positively theistic when not quite pantheistic, he was, spite of that common interest, anti-Cartesian.

More than this, his general mood was, or certainly came to be, very skeptical. Doubt had actually made Descartes and his philosophy, but Pascal came to declare that all the philosophy, evidently meaning all the systematic thinking, all the rational construction in the world was not worth an hour's attention. He was, then, a profounder skeptic than Descartes. Avoiding applicable systematic thought altogether, he had also left the pure, free knowledge of mathematics, which of course got its exactness and rational truth at expense of applicability and which for being so formal only gave a sort of visionary gnosticism, and turned to the more practical self-evidences, the immediate insights, of religion. So, as a skeptic, did he even outrun doubt itself.

Small wonder that he has not seemed quite respectable or technically correct among philosophers. Philosophical doubt must mind the traffic ordinances. It must not go too fast for safe and systematic reasoning Yet speed, or doubt even to the point of irrationalism, is sometimes justified and Pascal, in my opinion, deserves a place even in the histories of systematic philosophy. He made, not the usual, but nevertheless a real contribution. I would not injure serious discussion by a humor that may seem strained. Pascal, however, doubts all philosophy very much as Epimenides, as the only honest Cretan, doubted the honesty of *all* Cretans. Pascal philosophized a good deal, but to the cherished refrain that all philosophy was quite in vain, meaning possibly, not that there was no truth anywhere, but that philosophy, like many another thing in life, to gain its soul must lose its world.

"There is nothing," he says, "so in conformity with reason as the disavowal of the supremacy of reason." And again: "Two extremes: to exclude reason; to admit reason only." So in faith he found, when all is said, not unreason, but even more reason than in reason itself. Even philosophically there was something constructive in that. As philosophy is only superrational science, so religion, after Pascal, may be only superrational philosophy.

If what has now been said be correct or even plausible, the expression of Pascal's skepticism in his life may have a different meaning from what appears to casual view. In particular the anti-Cartesianism to which he came and with which came his retire-

ment to the Abbey of Port Royal, would appear to be, say what one may of the great change in his life which almost over night seemed to transform the scientist and mathematician and perhaps potential Cartesian into a religious recluse and saint, no mere "translation" or "conversion"[4] in any orthodox sense. By no means was it an awakening merely to some seventeenth century Fundamentalism. Nor will Pascal's great love for his sister, already conspicuously identified with the Port Royal group, or the accident or shock of 1649 afford adequate explanation. Moreover, there can be no satisfaction in treating Pascal as just one more psychopathic case. In Pascal after 1649, whatever the attending incidents or conditions, I see, I think with sufficient clearness, the open, released expression of implied but theretofore largely suppressed attitudes or feelings, not merely of the Cartesian philosophy with its coincident proofs of God and of a mechanical natural or physical world, but also of that more general rationalism, the wide mathematicalism of the time, then so significant at least not less religiously than naturalistically. I mean, again, that the mental complex and general import of that rationalism gave special character to Pascal's awakened religious insight and feeling. Even as if out-Descartes-ing or outspeeding Descartes, Pascal simply at that crisis became what any good and well-behaved Cartesian, if realizing the emotional and spiritual values, while escaping the mere rational forms, of Cartesianism or of the general idealistic rationalism, might have become. Shock of some sort and the deep experience of it may have been important as proximate cause; outwardly, too, the ensuing change may resemble an orthodox transfiguration; but not so easily may either the leopard change his spots or the intellectual his complexes.

III

A little generalization, if not too stimulating, is sometimes good for the mind.

One may well wonder if intellectuals of any stripe or spot do not commonly fail to realize, at least so long as they remain intellectually garbed and motivated, that their concepts and attitudes, their mental abstractions, methods and constructions, involving as they do both specific form and specific content, must always be potent at least with latent emotional possibilities, which sometimes have to find release and which upon release, even while taking anti-intellectualistic forms, are or properly may be only natural and evolutional expressions of the very mental life that they appear to supplant. Thought, in other words, always has values as well as forms and these values have to be realized, the intellectual giving

place to the emotional, intuitive and practical. The natural end of thought is will and where will is there value is. Again, perhaps with unnecessary repetition, there can be no reasoning without a life, even a superrational life behind it and sooner or later this superrational life must quicken the life of reason and so lead reason itself to find its own realization in feeling, heart, immediate insight and in the action so induced.

Historically or biographically, as I would submit, eras or periods of emotional insight or intuition are significant, of course for their often very obtrusive defiance of reason, but also and more positively for the way in which they show reason with its ways and forms from being held and cultivated for its own sake become only mediate and made quite subordinate to the life that is rationally not normal. "All our reason," wrote Pascal, "reduces itself to feeling. . . . . . We should have a rule. Reason offers itself; but it is pliable in every sense; and thus there is no rule."

Quite to the point, too, is another general fact. At least we may count it as another, although it is really only an expansion of what has just been remarked. Utilitarianism lives at least next door to rationalism. Throughout all the departments of life reason has ever made the sacred, conservatively cherished things, customs, institutions, standards, only so many utilities, so many means or symbols of some broadened or generalized end instead of any longer ends in themselves. Reason, in short, not merely rationalizes but also secularizes what it touches, making—if with whatever compounded offense I may borrow a startling if not profane pun—even divine Zeus only the Zeusful or—now to make prompt payment in kind for the loan—the magnificent Louis only a common and exchangeable *louis d'or*. Yet reason itself, while inducing such changes, never really completes the secularization. It may release to cold and calculating exploitation once cherished institutes of church or state, of morality or industry, but for full release and free use it lacks a needed abandon and the courage and adventure of abandon. Its utilitarianism is still in effect conservative or miserly, always making reservations, being still narrow in its spirit, however broadly rationalistic. For full release and free use, life taking quite to itself what has been fabricated for it, reason itself must turn only means to an end and give first place to feeling or faith. The very skeptical attitude that effects such a change—shown, for example, in the time of the Sophists and the Socratic philosophers as well as in the seventeenth and eighteenth centuries —has always been a solvent by which life has come to use freely, even with abandon that may suggest violence, instead of just hoarding intact, its various achieved and for a time cherished devices. Moreover, when at last the free, full use comes, reason having quite

yielded to emotional insight, and when accordingly the secular and useful things have lost their artificiality, being once more even as means or symbols intimately identified with life itself, these very things may recover the direct and vital reality or value which for a time the formal reason had seemed to deny them.

An example of the feeling or faith, of the irrationalism and abandon, of the virtual superrationalism, of which I have been speaking, can be seen in the century following that of Pascal and at least in a general way may assist understanding of our philosopher-saint. In the later century the rationalization and secularization of Christendom's customs and institutions had become very general and very evident. I have in mind a general situation, but I am thinking specially of Diderot and the Encyclopedists and I am recalling how Rousseau, as if the irrationalist in the drama, greatly disappointed those intellectuals. Devotees they were of the most rationalistic Illumination and they dreamed—as such Illuminati never should have dreamed!—of bringing everything out into the open and luminous air of reason, of clearing away all mystery and even of listing alphabetically and fully reporting and defining all things on earth and in heaven. So they dreamed and they had been looking hopefully to the young Rousseau as one who was going to add the reasoning powers of his genius to the support and furtherance of their cause. Exactly so at one time might the Cartesians have placed hopes in Pascal. But the young Rousseau, I was recalling, disappointed those visionary Encyclopedists, almost in their very midst raising his passionate and revolutionary outcry against calm, cold reason, its clearness and all its artifices and conceits, and calling earnestly for feeling and heart, for nature and reality, for real life, real justice, real religion, even for a real Christ. It is in truth a far cry from Rousseau to Pascal; but Rousseau was one of the irrationalists or superrationalists of history. In his case, too, abnormal personal experience seems to have acted as a proximate cause of the break with what was vogue among the intellectuals of the time. He cried for reality, asserting his own good will, when by all the standards of civilization his conduct of life had been a notorious failure, and with all this he was sensitive superlatively. David Hume said of him that he had the sensitiveness of one with the outer skin removed and every nerve exposed.

Still the emotional over-sensitive Rousseau did not deny reason or the worth of its manifestations in law and order. He simply insisted on its or their only mediate character and accordingly quite subordinated reason to nature and reality. By and of themselves the constructions of reason, law and order, boasted signs of civilization, were for him in some sense unreal, breeding only inequalities among men, injustice and artificiality generally; but, given their

proper place, made secondary and merely instrumental, they had a place in real life and partook of it, carrying it forward, and contributing to its worth instead of betraying it. Reason and its law for real life, not life for reason and its law, has been a principle of progress and strikes me as very near to the meaning of Rousseau's call for heart and reality.

Philosopher of the French Revolution and its abandon! So often has Rousseau been represented. That revolution, however, is best looked upon as but an unusually violent episode in the social and political evolution of the time through which conditions of special privilege and inequality were opened as opportunities to all Institutes of special interests became public media or instruments. By subordination of the old order as rationalized and secularized, to "Liberty! Fraternity! Equality!" not only was the magnificent Bourbon made merely so much exchangeable coin, but also the traditionally august things generally were put within popular reach and, from seeming dead, were made to live again. *Le roi est mort! Vive le roi!* Reason had secularized what feeling, not without some gestures of violence, sanctified anew by putting to progressive use.

IV

But let us have done with digressive generalization, however good it be for the mind, and with the emotional and irrational Rousseau, who certainly did not frequent the streets or walks of life best known to Pascal. Of course I mean nothing uncanny; but, while I have been speaking of Rousseau, Pascal himself must have been waiting aside, waiting and greatly wondering. That in any way his anti-Cartesianism or his irrationalism should be supposed commensurate with the passion of Rousseau! Rousseau was a social and political revolutionist or evolutionist; Pascal, only some sort of a philosopher and, in particular, a religious recluse and saint, who was also, yet very gently and in no sectarian sense, say in character and spirit rather than in avowal or overt act, a real protestant.

Pascal may not have had any very direct influence on life in general, on so-called practical life, social or political, whether for his own time or later; but he did effect something for religion and religious experience and in what he did here his work has a certain analogy with that of Rousseau. Thus he greatly broadened and deepened the mediative value of the institutes, the rites and sacraments of the church, with which, especially after 1653, he became so intimately identified. Perhaps, had he not been an invalid, had he possessed more vigor, he had not adhered so closely to the church as it then was; he might have not merely enhanced and enriched

the mediation, but also demanded and devised changes in the medium: but so to speculate is rather futile and in any case our interest here must be primarily in what he did, not in what he might have done. His actual achievement, too, was great and it had a quality worth while in itself and possibly quite lacking had he been able to be more practically inventive and openly progressive. Enough for us that his free broad spirit has belonged, not just to the visible institution of his time, but to the invisible, to religion then and since.

To begin with, spite of his anti-Cartesianism, Pascal really did carry on for Cartesianism and for the general mathematicalism and rationalism of the time; feeling these, however, rather than thinking them, making them enrich life emotionally rather than satisfy it only intellectually; realizing, even under the routine of a medieval abbey, their greater spiritual value. Like many other saintly, if not always sainted, individuals of the Roman Church he made the traditional tenets and the sacraments spiritual symbols and cults, using them as so many media in expression of an expansive Theism and broadly sympathetic humanism and so proving himself in reality more modern than medieval, for his time more naturalistic and humanistic and individualistic than institutional. It is true that in all its rites and disciplines his religious life, besides being outwardly conservative and reactionary, was very realistic, sensuously so; but I submit that for him, as to some extent for the medieval church generally, there was modern value in that sensuous realism. Also, if so I may express myself, the window of Pascal's cell was never really closed to the world that such men as Galileo and Descartes had discovered and as was already, for all whose windows and hearts were open, enriching wonderfully the old theism.

In the mathematicalism of the time, as developed by Descartes or by others, there really moved and moved forcefully the very attitudes and emotions that came to possess Pascal so completely. For evidence we should remember that to all intents and purposes the mathematical rationalism with its splendid enlargement and liberation of thought not so much replaced as continued the medieval formal and deductive logic, pious science of the Word, the λόγος. The former, in fact, may be regarded as only a brilliant generalization from the latter, as if deductive thinking had simply broken away from its tether of institution or dogma or single "given" or datum and entered the wider region of all data, say of all possible hypotheses. Even must one wonder if we ever would have had the mathematics without the earlier logic and its discipline. Many a churchman certainly was schooled in the logic only to be graduated a brilliant as disciplined mathematician. On this

bit of speculation, however, I need not dwell. Here it quite suffices, I think, to say that many have missed the great spirit of the medieval scholasticism, the reverence of its logic and the spiritual realism of its intellectual formalism and artificiality; and, missing these, they have not been disposed to appreciate how the ensuing seventeenth century mathematics, only fulfilling the logic by realizing and freeing the spirit of it and escaping the narrow letter, was also in the value given then, in the feeling of many of the mathematicians themselves and in the actual uses to which the great method of mathematics came to be put, a sacred science, being spiritually, not merely physically significant.

Most of us, quite unfortunately for full understanding, have commonly associated that mathematics and even the broader mathematicalism only with the rise of physics and mechanics or of a materio-mechanicalistic philosophy. Possibly as historians we have been able to drive only one horse, whereas whole and accurate history, I venture to insist, is not by any means so easy or simple, being actually drawn by two, not just by one with perhaps a colt. At least, as to the matter in hand many of us have not realized, even if we have known, that politics and morals and above all theology, from being at once narrowly institutional or legalistic and creationalistic, were also become with most important results mathematicalistic and mechanicalistic, the latter even to the point of suggesting a sort of automatism in place of the earlier creationism or control *ab extra*. All that those various terms mean, as I have just used them, may not at first appear; but it is at least clearly important to their meaning that the natural sciences and the humanities, including even theology, were met in the common method of mathematics. It may also be added in passing that quite consistently with that common method, the humanities, concerned no longer with traditional authority and institutional conformity but primarily with general and essential principles, with native powers and potentialities, capable of unlimited expressions or applications, were become or becoming directly human and individualistic, while the sciences on their side were inductive, objective, naturalistic. So, truly, had seventeenth century mathematics the historic value of the λόγος, mediating as it did in a timely way between the spiritual and the natural or physical.

Giordano Bruno (1548–1600), something of a mathematician, as well as psychologist and astronomer, and a good deal of a pantheist, was a martyred pioneer of those who can give testimony to mathematics at that time being significant at least not less for religion and the other humanities than for physical science. The moral and political writings of Thomas Hobbes (1588–1679), so formally rationalistic and *a priori*, afford from English history an

excellent illustration of mathematics as a humanity. Benedict Spinoza (1632–1677) gave not merely the spirit but the actual form and manner of a treatise of geometry to his famous *Ethics* and in this geometrical treatise, in its several Euclidean books, God and Nature, Mind and Body, Emotions, Bondage and Freedom, he included theology, philosophy of nature, theory of knowledge and morals and religion. Alexander Pope (1688–1745) and others like him across the channel well reflected the spirit of the time in their crystal clear and automobilic verse. A statement of Hume belongs, it is true, to the later time of Rousseau, but it expresses the tendency distinctly evident and, as we have seen, often exemplified in Pascal's century. Hume, who was fêted in Paris, saw no reason why even politics should not become a science as exact as mathematics. Doubtless to-day there are persons who wish Hume's dream might be realized! But plainly in the century of Pascal and the Cartesians mathematics, whatever else must be said of it, was a humanity comprehensively and profoundly.

For the whole Cartesian School this was eminently true. For them the very values of religion were in mathematics, making it, as was said above, a sacred science. With Descartes himself it brought not merely a remarkable expansion of geometry, effected by the admission of algebra and the device of coordinates to geometry, but also a proof of the existence of God which, judged by its sequel in Malebranche and Spinoza, freed theology as much as it had freed geometry, expanding as it did the life and purposes of the deity from the régime of the traditional church to the whole mechanism of nature In Book I of his *Ethics*, Spinoza proved mathematically, if not the identity, at least the virtual unity of God and nature. For Geulincx and Malebranche, both mathematicians and pantheists, life—or motion—and vision—or thought—were "in God," in the veracious God, veracious as mathematics.

So it is indeed well to remember that the humanities as well as the sciences were dependent on mathematics, that contemporary with Galileo (1564–1642) and others studying the physical universe, there were the devout Cartesians I speak only as a historian, but Pascal, reading the Psalms, out of the rationalism of his time could give special meaning to the nineteenth: "The Heavens declare the glory of God and the firmament sheweth his handiwork."

To the sacred science of his time, then, to the religious use and value of it, Pascal responded. Not a Cartesian technically or formally, not a philosopher of any ism, disposed on the contrary to disparage formal philosophy, he still can be regarded as deserving place in the history of philosophy for really being an important exponent or interpreter of the thought of his time, realizing emotions and values latent in it and so belonging to its meaning.

Was he, therefore, as has been suggested, super-philosophical rather than really anti-philosophical? Let a recurrent idea, or refrain, of his own writings give at least a partial answer. Nothing, as he keeps saying in various ways, is so consistently and consequentially rational as that reason is not all or philosophical as that no philosophy is final. To quote directly and at random from his "Thoughts":

> We know the truth not only by reasoning but by feeling and by a vivid and luminous power of direct comprehension and only by this last faculty do we really discern first principles. . . .
>
> If we submit everything to reason our religion will have no mysterious and supernatural element. If we offend the principle of reason our religion will be absurd and ridiculous. . . .
>
> Man is but a reed, but he is a thinking reed.

Yet many, I doubt not, will continue to think of Pascal as a traitor to the intellectual, to science and philosophy and reason, and will regard him, however admirable in his character of a saint, as only a reactionary who spurned instead of in any way fulfilling or valuing positively the science and philosophy of his time. Moreover, as must be admitted, they can make a plausible case. But they will be regarding the more external evidence and neglecting the real spirit of the man himself. Here is their case. He became a recluse in an abbey established in the thirteenth century and still on the whole in good thirteenth century character. With other followers of Jansen he went back to St. Augustine of the still earlier fourth century. He was mystical, ascetic, supernaturalistic. He even wrote very often in the language, to use our current term, of a Fundamentalist. But, so much said and emphasized, their case has its weakness. Of course, even such appearances may be deceptive. Returns to the past are ever of two sorts and to casual observation one sort may not look different from the other. Moreover, the neo-Augustinianism was actually broadening and liberating to thirteenth century establishments. Jansenism, again, was a movement against Jesuitism. So, if Pascal went back to the past, he was hardly a mere reactionary. He went back, not for dogmas, but for values; not for finalities, but for sanctified symbols. At the Abbey, as I have suggested, his windows were open to the new world of the time and his disciplines, however reminiscent of earlier centuries, were in worship of the expanded God of Bruno, the Cartesians—some of whom were also Jansenists—and Spinoza. There always may be, as in Pascal's case, as in Rousseau's case, something progressive, something even revolutionary in a cry, spoken or implied, for a return to the past. One may recall the past simply to hoard it or as with Pascal really to use it in the present.

Pascal's physical weakness after 1649 doubtless did affect the manner and meaning of his retirement and his outward defection from the intellectual for the religious life, but, under whatever qualifications this might entail, there is abundant evidence, which is not without its moral for certain reactionaries of to-day, that his retirement and reaction were without either bigotry or fear of truth. For the alarmed and bigoted reactionary "the end justifies the means" with a meaning which no one could ever suppose to be included in Pascal's philosophy of life. By his spiritual, not dogmatic fundamentalism, Pascal may properly be grouped with certain saints who returned to origins and fundamentals in a way that was indeed painful and was often too literally realistic, but who by making their religion so intimately personal instead of institutional were real Catholic forerunners of Protestantism. Did they not assert their individual independence and, like Pascal, have their windows open to nature?

Pascal, too, never really ceased to be a thinker, psychological, humanistic, candidly naturalistic. His "Thoughts," true to this title, show a reflective mind. More sporadic and aphoristic than systematic, it is true, they nevertheless are reflective and demonstrative, not dogmatic, in their spirit. Nowhere, so far as I have found, is there any defiance of science or reason. Were the "Thoughts" to be initialed, the appropriate letters in signature would be Q. E. D., not W. J. B. Living to-day, Pascal would not have denied evolution.

Primarily Pascal stood for spiritual values, not for outgrown and rationally no longer tenable doctrines. "If we offend the principle of reason our religion will be absurd and ridiculous." Pascal, I repeat, greatly broadened and deepened the mediative value of the rites and sacraments of the church. Stronger, he might have done more; but he did so much.

VI

May I conclude with some possible applications to the present day?

So far I may have seemed to be speaking in an untimely way, arousing surprise. I have been, or have seemed, so ready to accept the language and take the standpoint, not merely of general orthodox theism, but also even of Pascal's Romanism. Yet, attempting to write as historian and biographer, how could I have done differently? Seeking to represent the Augustinian Pascal and his time, quite apart from any religious color of my own or any lack of such color, I could not be true historian without the sympathy I have shown. Lacking such sympathy, I had in so many words accused Pascal of not being genuine. He certainly was genuine and true to his time.

In my sympathy with Pascal and applause of him I may, furthermore, have caused alarm among the intellectuals, philosophical, mathematical or scientific, who now attend. "Would he start a revival among us?" I hear someone ask: "Would he summon us to the front pews, to which the scientist and mathematician, Pascal, finally came and ask us also to become devout theists or retiring saints instead of critical and systematic intellectuals? Would he have us believe that naturally in our intellectual life there lurks any such danger?" Let no one be so frightened. Here and now is no intent of a revival. Also it may even be that twentieth century Illuminati are latently also Religiosi and that our various intellectual isms and systems hold spiritual values which some day will be realized by others if not by ourselves; but my present interest has been simply to understand Pascal—the Pascal between the lines of the formal life of his time—and to make clear for any time, our own or any other, as well as his, the general principle under which he can be understood. Given isms or systems, they can not always remain merely intellectual or rationalistic; in them lie more than so many facts and formulae; in them are present and potent specific emotional and volitional values.

Many there are to-day for whom the world seems to be only a world of facts and formulae. Hiding their inevitable interest in it or their own conceit of wisdom about it, either of these certainly implying real valuation, they would represent it only as a world of facts and formulae. Perhaps they treat the values as only more facts, humanistic instead of naturalistic facts. Perhaps they are satisfied that at best the values, so far as not just facts, are only relative, subjective, virtually elusive and unreal, varying with the weather. But as to their boasted facts and formulae, are these on their side so real and stable, so true and reliable that the world of values may be disparaged and discredited for its fluency and adaptability? I would be the last to insist on two worlds or on any real dualism of facts and values. Values, however, are as real as facts, so that quite contrary to what many have been contending in these days of naturalism and science, no factual realism can be adequate to, or exhaustive of, reality or be in its so-called realism more than an important half-truth. A realism proceeding from the facts and formulae of natural science can at best be only an abstract and artificial construction. Can values be objectively rationalized or facts be confused with feeling and will?

I am no theologian and theologically I certainly have no brief for Pascal. From anything of that sort I am farther removed than what I have been saying here may have seemed to imply; but to the extent in which Pascal caught and expressed, as if in a counter

abstraction and construction, the feeling and spiritual meaning of the rationalism and broad mechanicalism of his time, expanding the old theism, purifying and deepening the accompanying personal individualism and making even traditional rites and disciplines serve his naturalistic pantheism and his virtual protestantism, I have found myself constrained to approve and applaud.

A final suggestion seems not impertinent even in this place. Our current newspapers and journals are each week more and more given to references to a coming spiritual awakening. Some would explain such things as give ground for these references by calling them gestures of weakness. So always in their view has idealism or spiritual realism been a sign only of atrophy or "nerves" or defect and natural incompetence of some kind. The substantial progress of thought, except for somehow persistent and discouraging idealistic lapses, has been a gradually preparing triumph of so-called natural realism! But such explanation can not satisfy either history or the present day. One-horse thinking I have called it. Let it stand and the sort of thing that Fundamentalism is exhibiting seems inevitable. Insist only on the natural facts and formulae and you invite a purely reactionary Fundamentalism, its ignorance and narrowness, its timid retirement and bigotry. With candid acceptance of the facts, then, there must be also as the only way in which really to complete the realism or the naturalism, emotional and volitional valuation of them. In other words, such movements as Fundamentalism must be met in kind, and met in kind, not indirectly and half-heartedly, not with uncertain and equivocal adjectives, but directly and positively, with substantial and unequivocal nouns.

Does this mean that the idealists should propose a new vocabulary for their wares, bringing their nouns up to date? Doubtless something might be said in support of an affirmative answer to that question. The call for a new language when meanings have greatly changed is a familiar one; as familiar, too, as unwise and unfair. But, whatever the grounds for it, surely idealism, or the realism of values, ought not to be required to devise new terms until the counter abstraction, the realism of facts and formulae, is ready on its side, instead of any longer talking of nature and matter, of force and life, to tell us of kibosh and woppy, of joteb and jazz, or of other things as novel and startlingly up-to-date, as also uninteresting.

THE VALUE OF INCONSISTENCY

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"A FOOLISH consistency is the hobgoblin of little minds," was the opinion of Emerson in an essay on "Self-reliance." He thought that one should speak in hard words what he thinks to-day and to-morrow what to-morrow he thinks, though the two might be completely contradictory. This opinion is a frank acknowledgment of growth in comprehension or of significant changes in circumstances or of both. But it is not universally accepted. In fact, quite commonly consistency in belief is thought to be a matter of unexceptional necessity for the individual. It is an accompaniment of sincerity, thoroughness and honesty. An inconsistent candidate for office will not get our votes, for in inconsistency there is a flavor of untrustworthiness, indeed of dishonesty. So firmly fixed is the faith in consistency that in the life of the individual it has been accepted as a virtue possessing an inherent value independent of circumstances.

Doubtless the origin of this faith in an individual can be found in his past experiences. A child as a listener to debates in the family circle learns the crushing influence of the proven charge of inconsistency. The pulpit expounds doctrines that give satisfaction not only in themselves but more importantly as component parts of a consistent system of belief. Even arithmetic teaches the necessity of consistency in the use of units such as feet and yards, if the correct answer is to be obtained. When the child becomes a college student there is no abatement of instruction in the virtue of consistency. Thus one comes to regard that virtue as really inherently valuable and always essential to sound and permanent progress. Such instruction in the use of consistent reasoning is commendable. An opposite teaching would be disastrous. But the question is raised: Is consistency inherently valuable and always essential? That the ultimate is wholly consistent is not here doubted. Moreover, one may take the view that, in view of this admission, consistency must be regarded as inherently valuable and always trustworthy. But this discussion refers not at all to the ultimate, but to the thoughts and reasoning of the individual. With this understanding, one can at once recognize the possibility of the measure of the value of consistency by results achieved through its application.

It is easily seen that an expectation of the possibility of the constant condition of consistency is not justified. For consider the

nature of truth. We do not have it all, but only fragments of truth, and since each of these can not be perfect in every respect, they may overlap in their applicability and in this overlapping region may not be in agreement. An example in physical science will illustrate. Consider the physicist's knowledge of interatomic forces. There is undoubtedly an attraction between bodies of matter, and to this is given the name gravitation. The law of gravitation, whether one accepts the simple form of Newton or the amended one of Einstein, asserts that the attraction increases with a decrease of distance between the bodies. But this law, which is believed, is inconsistent with certain phenomena found at small distances. In crystals the atoms are in orderly array with their centers at fixed mean distances which are not limited by contact but evidently by forces which prevent a nearer approach. Obviously, the law of gravitation is not in harmony with this fact, for it claims that attraction is always present. The supposition that there may at these small distances exist a new type of force in addition to that of gravitation is merely an effort to remove the disagreement between accepted "law" and experiment. The physicist admits the contradiction, asserts that you have applied the law at distances not justifiable by experiment and that the complete law applicable to all distances has yet to be ascertained. The law of gravitation is a fragment of truth, not perfect, and consequently not always in agreement with the actual phenomena. The physicist at every boundary of his knowledge sees the chance of contradiction of theories or scientific beliefs. It is moreover strikingly significant that in these inconsistencies he finds the challenge that leads to new investigations and to new knowledge.

From the foregoing it may be observed that the considerations of this paper are not limited to the inconsistencies to which Emerson refers. These arise from opinions held at different times. It is here purposed to show that *simultaneous* inconsistency or holding at the same moment contradictory opinions or theories is not wholly undesirable and may even be a necessity for progress. Science and more particularly physical science has, by the application of what is known as the scientific method, produced a permanent body of knowledge which is proving exceedingly useful to mankind. Physical science is always logical, but it often limits its effort to the clearing up of a small region of knowledge, and in so doing establishes consistent views, not necessarily in science as a whole, but in this limited region. In short, progress through consistency in a small domain is sometimes a desideratum even at the expense of consistency throughout the entire body of knowledge. Thus it happens that a simultaneous inconsistency can be helpful to progress in physical science, and, if so, surely in less mathematical and less

logical fields this type of inconsistency may prove to be of even greater value. This presentation substitutes concrete evidence for an argument covering the entire range of man's thought, expecting that a definite knowledge of the possible value of inconsistency in physics, for example, will thereby carry a reasonable assurance of the existence of this value in all fields of knowledge.

That the ultimate goal, truth, is everywhere consistent should not cause a reliance in such a harmony in any of the series of immediate goals that are attained in man's progress. In fact, too strong a hope for consistency may become an actual hindrance. This was Oersted's experience when endeavoring to discover the effect of electricity from galvanic cells upon a magnetic needle. The phenomenon itself is experimentally simple. When a current in a wire is held over a magnetic needle, the latter turns and would finally point at right angles to the wire were the current the only directive force. In Oersted's time the experiment was not difficult of performance so far as equipment was concerned, for the galvanic cell and magnetic needle were well known. The real difficulty which Oersted had the honor to overcome was that of experimenting in a manner inconsistent with the thought of the day. Oersted states in his original report of these researches that he experimented with a closed galvanic circuit and not with an open one as had been unsuccessfully tried by several distinguished physicists. Any ignorant boy might have tried one method as readily as the other. But learned physicists, fully aware of the best thought of the day, failed to find the phenomenon because they experimented in a manner consistent with current views. Yet how importantly did consistency retard progress, for upon the magnetic effect of a current of electricity rests all the modern utilization of electricity.

Another illustration is found in the life of Faraday, the great discoverer of induced currents. He was delayed to an unbelievable extent by his attempt to be consistent in his reasoning. He knew that, as Oersted had shown, a constant current produced a constant magnetic field. If there was a reciprocal action, then a constant magnetic field would produce a steady current. He attempted patiently to prove this but failed. Not until he laid aside his attempt at consistency did he learn the actual relation, namely, that a changing magnetic field and only a changing one will produce an electric current. If he had been unhampered by apparent consistency in thought, one experiment would have been as easily and as quickly tried as the other. In view of such actual occurrences with the world's greatest investigators, it is easy to believe that thousands of experimental efforts have been brought to nought because the investigators did not overcome the hampering influence of consistency with known facts.

It might be anticipated that if consistency may be a definite hindrance then at times the adoption of an inconsistent theory may prove advantageous to progress. Such is the fact. When Bohr first described his orbital theory of the structure of the atom, many physicists were dismayed because Bohr assumed the truth of the recognized laws of mechanics and of electricity *only in part. Without any other justification than the results achieved thereby* he made an assumption contrary to an important conclusion from these laws. This heresy of eleven years ago is to-day orthodoxy and yet without any other kind of justification found for the assumption than the one Bohr made. The confusion arising from inconsistency has not been removed, but the essence of the orbital theory is accepted to-day as a permanent contribution to physics.

Other illustrations of the adoption of theories inconsistent with those already accepted may be cited. For example, a mathematical expression for the radiation from black bodies could not be obtained by adhering to classical (or accepted) doctrines. Only when Planck broke away from them did a theory in agreement with the facts appear. So common has this apparent breaking with the past been productive that its significance should be emphasized. The great leaders in physics are not unstable radicals. They are in fact very conservative. They do not propose new theories in order to indulge in heresy with its attendant compensations in notoriety, but they propose theories that are needed to explain phenomena which are not understood in the light of the older views. The old is not cast aside. The new compels temporary acceptance on logical grounds. For the most part the contradictions between the new and the old exist in a region of experiment into which attempts had been made to extend the old, though not without logical reasoning. Always the old view is retained where it serves best to relate the facts and the new view is applied only where it gives the best explanation. Thus the leaders and indeed all who follow them accept doctrines that are not consistent in overlapping regions. The physicist of to-day may well be called a polydogmatist. His inconsistency does not cause him worry, for he realizes how far distant is the goal and how unproductive would be the requirement of consistency along the journey. Then, too, he becomes more aware that, after all, a doctrine is a thing to be practiced and not believed in the sense of inactive acceptance. His main object is to apply new doctrines, discover new facts thereby and thus to make progress.

Illustrations have just been given of the negative value of attempted consistency and of the positive value of inconsistency. No argument has been made to establish an inherent value for conflicts in views in the mind of an individual. The illustrations are merely

indicative of a fact, and not a theory, that progress in science is frequently made by the investigator when he harbors theories not free from discrepancies and contradictions. And the cause of progress in science is surely representative of most intellectual endeavors of man. Such evidences, if faced frankly, destroy one's confidence in the adoption of consistency as an ideal in every thought process. An effective and desirable combination of consistent reasoning and incompatible beliefs may be described as a striving for consistency in limited regions of thought, each one as large as practicable, accompanied by a regard for the consistency of the whole as a consideration of much less immediate importance.

The phrase "separate compartments" is sometimes used to describe the structure erected in the mind of one who has not a consistent belief. If one can not reconcile his beliefs, he must prevent quarrels among them by effective mental separators that forbid movement or exchange of thought from one realm to another. It is difficult to conceive of a great mind engaging in such an arbitrary means of securing mental peace. But the foregoing shows that in achieving progress such compartments are sometimes essential, for the new theory must have a chance. It must be tested in all directions and the whole measure of its truth taken without interference on the part of the old. The compartments are not consciously erected by the investigator, for he is absorbed in the outcome of his own efforts. He does not have time to become concerned with any possible inherent value in complete freedom from contradiction. Readers of the life of the great Faraday have wondered about his willingness to have such compartments. He would scarcely accept the experimental findings of another physicist without testing them out for himself. Yet he contentedly belonged to a small and very credal religious sect until expelled from it because he dined with the Queen on Sunday. Faraday waited patiently until he was reinstated in the fold. Tyndall, in referring to Faraday's religious view, states, "He believed the human heart to be swayed by a power to which science or logic opened no approach." In a letter to Lady Lovelace, Faraday wrote, "There is no philosophy in my religion. . . . I do not think it at all necessary to tie the study of natural science and religion together, and, in my intercourse with my fellow-creatures, that which is religious and that which is philosophical have ever been two distinct things." In the light of what has been herein set forth, Faraday's position can be understood. He was content with two compartments because he was so busily engaged in one that he did not have either time or interest in the problem of reconciling the two. Doubtless he also saw that consistency is not an inherent virtue and that indifference to it in overlapping fields may be the attitude of the mind that produces the most rapid prog-

ress. Under such circumstances it may be that a great mind erects compartments, but these considerations should not commend compartments as a fixed policy. It is wise, however, to understand clearly that compartments may, in individual cases, prove advantageous to real development. The analogy to the attitude of investigators in science is complete; always an attempt at consistency, but the adoption of inconsistent views if thereby distinct progress can be made. In contrast, one may imagine a mind so absorbed in reconciliation that he fails to contribute to any field of knowledge.

Since the methods of science are logical and not unique, the reader may have confidence that there are cases in all fields of knowledge where a willingness to be inconsistent has a distinct value. And, further, inasmuch as the method of science has proved its worth by the production of results, one may expect a fair inference that the contention in this essay may wisely be extended to one's attitude toward the political, social and religious questions of the day. It is distressing to witness the somewhat insistent belief of young people that religious faith and scientific knowledge must be in agreement. The scientific method has been adopted extensively in the accumulation of the latter. In religion the same method has been but little used. Although in a measure based upon experience, religion has been accepted more by faith than by experiment. It is therefore not surprising that the conclusions of theologians do not altogether agree with the views generally accepted in science. That there is no contradiction found in science to the most fundamental concepts of the theologian is far more important than the disagreements in minor details. While every one should wish for no conflict between science and theology, consistency is not an immediate goal and inconsistency must be anticipated as a normal accompaniment of progress in such widely separated fields. He who spends his time attempting to reconcile the teachings of science and of theology surely can not have a very important function in contributing to the progress of either. Scientific theories are to be *lived* and not merely *believed*. He who is engaged in the encouragement of the application of theory in either field is aiding in the progress of the world. By his devotion to a cause and his willingness to be inconsistent without worry, he can make a definite contribution.

Emerson was right; past opinions should not cause excessive mental inertia. But the above conclusions take us much farther. Inconsistency in opinions held at *one* moment may be necessary for progress and the individual should accept this view and cease to regard complete consistency as always either desirable or valuable.

PROGRESS—BY ACCIDENT OR PLAN?

By Professor EZRA BOWEN

LAFAYETTE COLLEGE

PROGRESS is a fact. But it is a painful fact. Can it be made less painful? Let us see. And to this end let us attempt to arrange the facts and principles of human progress in clear and simple pattern.

Progressing means adapting Man and his setting coming into smoother working adjustment—this is progress.

Two terms appear in the subject of this definition, "man" and "his setting." There are, then, to human progress, two phases: Man's nature changes to meet the conditions of existence; and he modifies the conditions of existence to suit better his present nature. The first proposition offers a study in life, biology; the second a study in livelihood, economics.

Progress of the first sort, biologic progress, is not accident; it is a necessity, a condition to existence. Concurrent building up and breaking down, the central characteristic of life forms, decrees progress—or extinction. And this process is present, in principle, in all that is organic or of an organic nature: in cells, in tissue, in organs, in individuals, in institutions, in society as a whole—concurrent building up and breaking down everywhere, universal to life. But always one outruns the other. There is no poised state in life; there is decay or growth. Progress is necessary to life; and the continuing existence of the human kind is complete testimony to its biologic progress.

But if biologic progress is no accident, neither is it a conscious product. There is no warrant, the biologist says, for belief in the inheritance of acquired characteristic (progress through passing on the acquired betterment of the individual). Nor does a regard for the biologic progress of mankind appear—if at all—except as the barest trace in the general mating motive.

What, then, are the factors in biologic progress? They are three: heredity and variation form each one side of the arch of progress; the keystone is propagation beyond the means of existence.

Heredity may well be considered the first fact of biologic progress, without which all would be senseless confusion. It is the tendency in individuals to resemble their progenitors. And, were

heredity the single fact of regeneration, each successive generation would be exactly like the preceding—in the same sense that one sheet of two cent stamps is like another struck from the same plate. But superposed, there is the fact of variation.

Variation is the tendency in individuals toward difference, in ways and degrees indefinite, but always within the meaning of the concept of heredity.

When the idea of variation is added to the idea of heredity, we see the vehicle of biologic progress complete; but still there is no motor. Propagation beyond the means of existence—here is our motor. This is the dynamic of biologic progress.[1]

Heredity insuring integrity, variation forming a basis for selection, and close-fisted nature, acting through over-propagation, doing the selecting—this is the progress scheme, complete. Nature takes the individual as he comes from the shaping hands of the sisters, heredity and variation; slams him, kicking, into an almost rigid mold, the conditions of existence. If he soon stops kicking and passes on to his reward, it is because he did not fit in with the conditions of existence. Others fit and are called fit. They propagate, and heredity shapes their children a little more to the mold, more on the average than were they and their non-fitting brothers, taken together—a millionth of a hair's breadth, perhaps. No whit better than its actual progenitors, a generation is, nevertheless, a millionth of a hair's breadth better than the whole of the preceding, misfits and fits lumped. Simply, the misfits perish before the time of propagation, or their children perish soon thereafter—only the more fit are reproduced. This is the natural method of progress; its price is eternal destruction.

The direct cause of this destruction, over-propagation, implies constant struggle and no quarter given. All other species must blindly carry on, but man—or some among men—know this grim

[1] Of course it is not, in reality, as simple as this; and what follows also preserves strict accuracy only in bold outline and relative position. The "forces" of heredity and environment, for example, are inseparable, except in complete abstraction—and so are heredity and variation. In fact, these three, merged to form a new concept of heredity—heredity in a cosmic rather than a parental sense—may be the only hope for the survival of the term heredity in the biologic language. There is a complicated interplay of chromosomes, cytoplasm and external accident that eludes the grasp of any term now in use. A certain egg is compelled by a force within to produce an individual of predetermined characteristics—that concept of heredity is outworn and discarded. It now means but little more than this: A certain frog egg is not predestined to become a frog of definite characteristics and markings, and a second egg to become an equally definite but slightly different frog. Simply, neither will ever become a canary—or even a hop toad. The main force is in negation.

joke. Then why have we not been shown the way to swim out of the terrible waters of over-propagation in which beast, bird, insect, bacteria and man struggle, group against group, individual with individual; wherein two plot and strangle a third that two may live—miserably in the main, but live? Were some prophet to show us that we ought to swim out of the whirlpool of over-propagation—and we did it—should we not, by that act, thwart progress and bring on the ultimate destruction of our kind? For if over-propagation is the motor of progress, and we limit births, are we not destroying the motor, bringing everything to a fatal stop? But what matter—why subject nearly all one generation to grinding, heartbreaking conditions of existence in order that the next may be better (better adapted) by the thickness of a wish? Ridiculous! Limit births and sack progress.

This is the point reached by the birth-controllist; this is his "furtherest north" in the general rush to reach the pole of clear thought in the problems of progress and population.

But it is not necessary to sack progress. For in limiting births you thwart only natural selection; and it is merely some kind of selection that is wanted. Will not conscious selection motor the car of progress more efficiently than the old engine, over-propagation—plus destruction? Beyond a doubt. And that (conscious selection) is the fundamental meaning in eugenics.

Now we can lay out the pattern, complete, of sane biologic progress: Limitations of births to reduce the pressure of the conditions of existence, and then, conscious selection to keep progress in the plan. . . . But this is only half of progress; we have still to consider the economics of it.

Progress is not of two independent kinds, but of two related parts moving in one direction—toward closer adaptation. We have seen that man's nature has been modified favorably, from generation to generation by but infinitesimal degrees. For tens upon tens of thousands of years his ability to modify his setting did not amount to more. But what weal, what wealth, has been piled up in the past one hundred years, in the last quarter century! Wealth, fixed wealth, especially: dwelling places, factories, highways, the housing of commerce, the machinery of transport—these and their like are the huge improvements man has made in the conditions of his existence.

The degree to which man has, in late years, ameliorated the conditions of his existence—an astounding economic progress—seems to many minds to have removed him from the universal strife, the struggle for existence. But these optimists have left

out of account rising standards of living. They have forgotten that human desires increase more rapidly than wealth. And it is, unhappily, the newer, complicated, more urbane desires that receive the greater emphasis. Here is a case from the record of abandoned babies in Minneapolis: A young couple, haled into court, said simply they had decided that either automobile or baby must go. They had given up the baby. Again, nearly 20 per cent. of the school children in the larger cities of the United States are undernourished, and the families of many support a "car"—hardly one foregoes both radio and phonograph. The fol-de-rol and flap-doodle of civilization must at all costs be maintained!

From this it seems quite clear that birth-control, and nothing more, is of no avail. For if the striving, starving family of eight be limited to four, only to afford soiled silks and second-hand motor—little ones still hurrying off to school, in winter, cotton clad and badly nourished—where is the gain? The consumption of goods and services, the utilization of wealth—this, too, must be controlled.

But it is not to be argued for one instant that lower standards of material living must obtain. To the contrary, higher and higher standards are most desirable—and as inevitable as they are good. Simply, the emphasis must be made to fall where it should. And until education has given every individual a sounder set of values, the use of wealth must be directed.

Now we have the pattern of sane progress, all points and lines intact: There must be limitation of births; there must be direction and control in the utilization of wealth—these to give respite, to give slack, to make life for the many an investment rather than a speculation or pure gamble. Then, there must be conscious selection to restore progress to the scheme.

BOTANIZING IN BOLIVIA

By Professor A. S. HITCHCOCK
U. S. DEPARTMENT OF AGRICULTURE

In going from Cuzco to La Paz the traveler passes through Juliaca, taking the branch of the railroad to Puno on Lake Titicaca. Here he transfers to a small but comfortable steamer and during the night crosses the lake to Guaqui, and here takes the train for La Paz. Lake Titicaca is 130 miles long, and as much as 900 feet deep, has an area of about 3,200 square miles and lies between Peru and Bolivia at an altitude of 12,500 feet. The scenery is not striking, as there are no high mountains in the immediate vicinity. The drainage system has no outlet to the sea; the waters of the lake flow south and are finally lost in the great alkali desert of southwestern Bolivia.

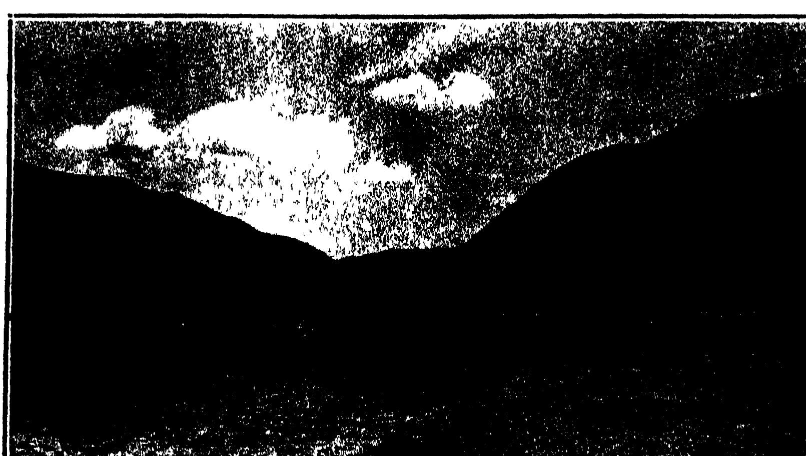
The plain to the east of the lake rises gradually to the rim of the valley of La Paz where it is 13,500 feet. It is a remarkable and surprising sight as one approaches the edge of the puna or plain and suddenly looks down on the city of La Paz, 1,500 feet below.

Scene in the Yungas
Semitropical vegetation of a valley.

A VILLAGE ON THE WAY TO THE YUNGAS

The train changes here to electricity and meanders down the steep slopes of the valley to the city.

At La Paz I had a good room in the Hotel Paris facing east and had a magnificent view of the great snow-capped Illimani 30 miles distant, rising to the height of 6,619 meters (21,700 feet). This imposing peak dominates the view here much as Ranier and Shasta



A DRY RIVER BED IN SOUTHERN BOLIVIA

In these desert regions, devoid of trees, the run off after the occasional heavy rains is rapid and floods pass through the valley with a roaring front 3 or 4 feet high, dangerous to travelers on the highway that uses the stream bed.

do with us, or Chimborazo and Cotopaxi in Ecuador. The view as the sun sets is especially striking, the glistening white passing into pink and purple and finally fading to a shadow. Another high mountain, Sorata or Illampu (6,645 meters) lies about 50 miles north of La Paz, but can not be seen from the city.

In the absence of our minister, Mr. Cottrell, the secretary of our legation, Mr. Flack, brought me in touch with many people who aided me very materially. In this he took special pains and added greatly to the success of my trip. Wishing to ascend one of the high mountains I chose Illimani as being most accessible and, in company with Mr Dagg, went by mule to a ranch on the side of the mountain, the trip occupying two days. On the third day we ascended to about 16,000 feet where there is a large glacier with a

MT. ILLIMANI LOOKING EAST FROM LA PAZ
It is about 30 miles away but dominates the view all over this region. Altitude 6,619 meters (about 21,700 feet).

front about 100 feet high. On the fourth day we returned to La Paz.

I had been in correspondence with Dr. Otto Buchtien, the well-known German botanist, long resident in Bolivia, who was then in southern Peru. I was fortunate in having his company on my next trip which was to the Yungas, the montaña region lying to the north and east of La Paz over the eastern Cordillera. Sr. Aramayo, the director general of the Yungas railroad, aided very efficiently by furnishing passes for Dr. Buchtien and myself to Pongo and mules and a man for our trip through the Yungas. The railroad is completed northward over the pass at over 15,000 feet and on to Pongo at about 12,000 feet. Here we took mules, three for riding and one for cargo, consisting of my cot and bedding, a supply of supplementary food, and collecting outfit. We descended rapidly to the forested region and by many ups and downs through valleys and

YARETA

Fuel at a railway station on the puna. Many carloads piled here for shipment. The plant (*Azorella monantha*) is a tussock plant growing near snow line.

over ridges passed through San Felipe, La Florida and came to Chulumani, all in Sur-Yungas, the last city being the capital. Returning we crossed over into Nor-Yungas and went through Coripata, Coroico (the capital), Bella Vista and back to Pongo. Dr. Buchtien was widely acquainted in the region and we were able to stop at several plantations with his friends.

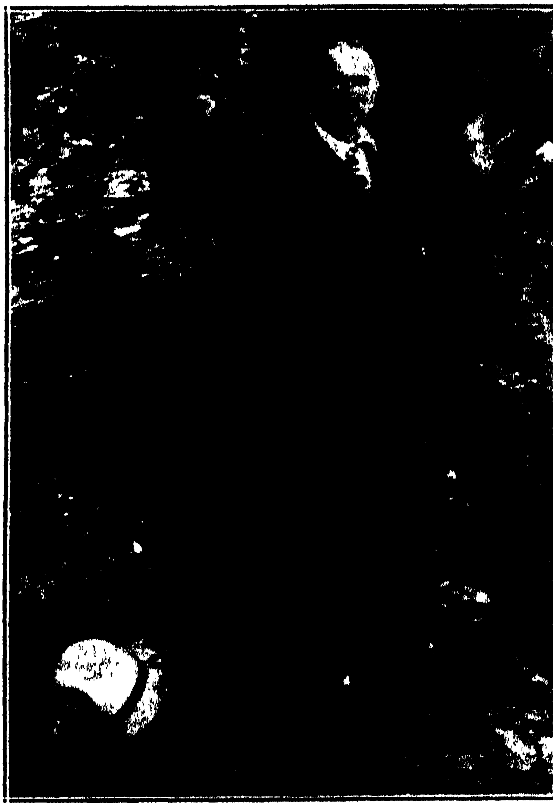
FUEL AT THE RAILWAY STATION

The wood is roots and gnarly stems of desert shrubs.

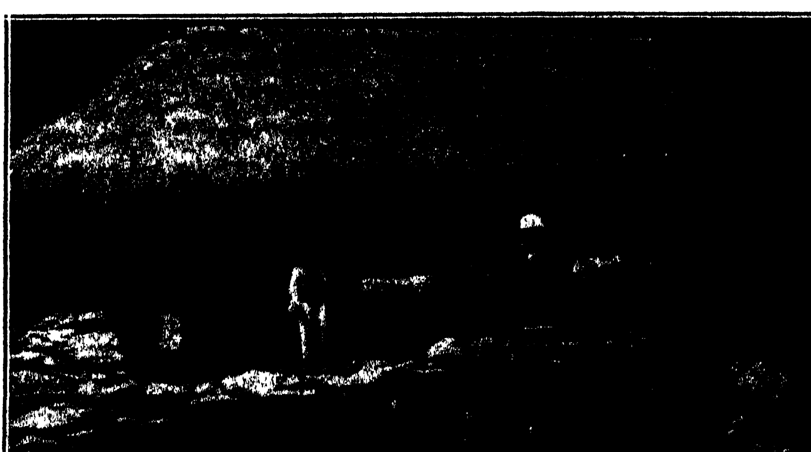
The trip was a hard one for ourselves and for the mules but I was surprised at the endurance of the animals. Seven days continually traveling, having no grain, nothing but alfalfa, corn leaves, cachi (*Axonopus scoparius*), or bamboo leaves, much climbing and descending 5,000 feet at a time, yet with no signs of collapse. I had my own saddle that I had brought from the states. The collecting was done as we traveled, that is, when I saw a grass that I wanted I dismounted and the helper brought the press, the plant was placed in papers and we proceeded thus, mounting and dismounting throughout the day. We succeeded in getting several species of bamboo in flower, which was good fortune as bamboos flower only occasionally.

SACKS OF COCA LEAVES ON THEIR WAY TO MARKET
Cocaine is extracted from the leaves but the leaves themselves are chewed with paste of ashes, by the Indians, as a stimulant.

The Yungas is famous as one of the chief sources of coca, the plant from which cocaine is extracted. The plant is a shrub somewhat resembling privet. The leaves are gathered, dried and shipped to the sierra where they are extensively used by the Indians as a stimulant. For this purpose the leaves are mixed with a specially prepared paste of ashes, and chewed as is tobacco. Almost every Indian man may be seen with a bulge in one cheek showing the location of the quid. The alkali releases the alkaloid which allows the user to work with less food and with less fatigue than normal. The shrubs are grown on hillsides in carefully prepared ditches in terraces. Coca should not be confused with cacao, an entirely different plant from which chocolate is made.

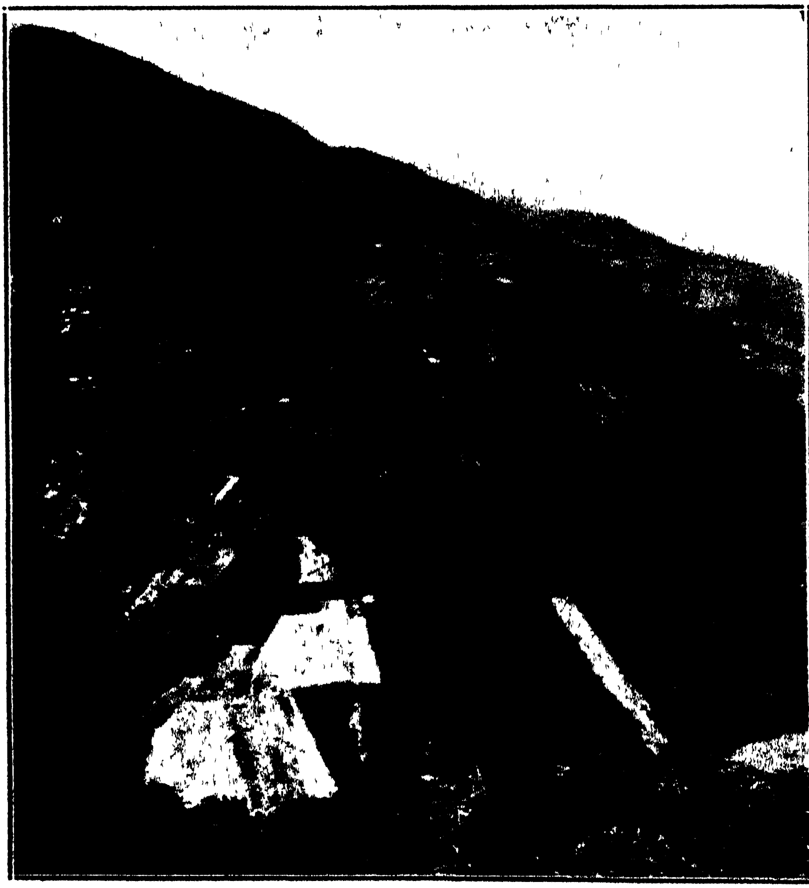


DR. OTTO BUCHTIEN
The well-known German botanist, long resident in Bolivia. He is very familiar with Bolivian plants and has published a flora of the country.



A HOTEL IN THE YUNGAS
Dr. Otto Buchtien in the foreground.

After returning to La Paz, I made arrangements to go to the southern part of the country. A letter from Mr. Flack to Mr. Trueheart, assistant general manager of the Ulen Contracting Corporation in La Paz, interested his friendly aid in my work. The company is building the road from Uyuni to Villazon on the Argentine border, and regular trains run as far as Atocha. Construction



COCA PLANTATIONS IN THE YUNGAS
The shrubs are grown in carefully prepared terraced ditches. The whole country is dotted with these fields far upon the sides of the mountains.

trains run for several miles at each end of the remaining distance, but there is a long gap through which one must go by auto or by mule. Mr. Trueheart arranged to furnish transportation on construction trains and to provide a man and three mules for the intervening distance.

On the way to Atocha, I made a side trip from Oruro by rail to Cochabamba, the center of a rich agricultural valley. Mr. Wash-

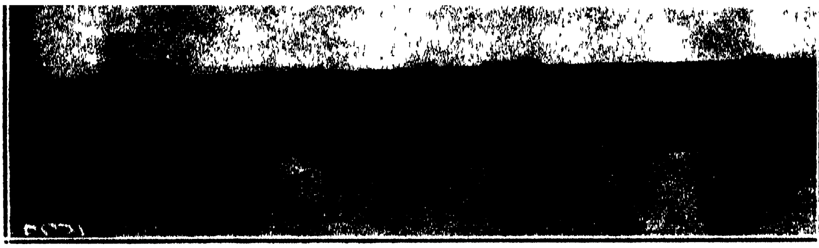
burn, head of the American Institute, a school for boys and girls, aided me here. Cochabamba has a delightful climate and is a pleasant place to live, being at an altitude of about 8,500 feet.

The southern part of Bolivia is arid and the xerophytic character of the flora is shown by the large number of cactuses. One large columnar species (*Trichocereus terschecki*) is a timber tree, the woody ring being sawed into boards, these being used for the construction of floor, doors and partitions. The trip from Atocha to

A COMMON WHITE-FLOWERED COLUMNAR CACTUS NEAR LA PAZ

the end of rails coming up from Villazon occupied three days. One cargo mule carried my cot, bedding and other baggage. I went on to Villazon and crossed over the line to La Quiaca in Argentina as there is a hotel at that place.

The road for fifty miles lies in the dry bed of the principal river of the region and passes through Tupiza, the capital of the province. Although dry most of the time, the valley is subject occasionally to heavy floods. Because of the lack of trees and sparseness of other



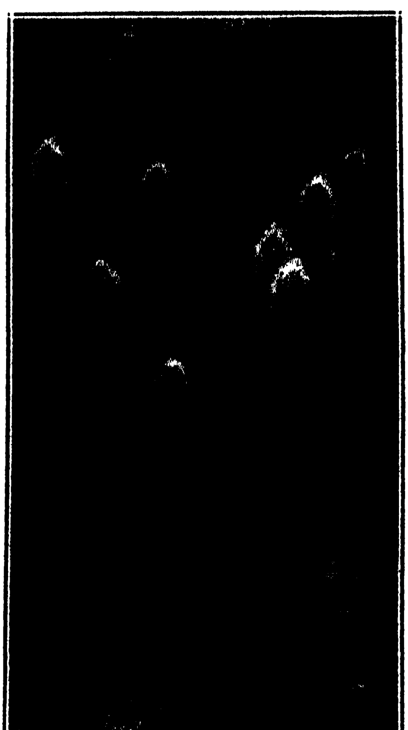
THE DESERT PLAIN AT UYUNI, SOUTHERN BOLIVIA

A LARGE TUSSOCK CACTUS WITH YELLOW FLOWERS
On the desert plain near Uyuni, southern Bolivia. The tussock is about 2 feet high.

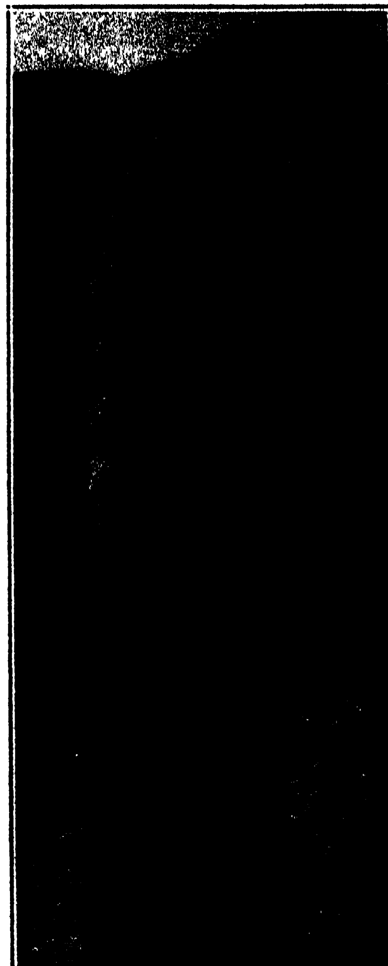
ERODED RIDGES BETWEEN ILLIMANI AND LA PAZ
Xerophytic shrubs in the foreground.

vegetation, the run-off of the water from the surrounding hills is very rapid and the flood comes down the bed of the river as a wall three or four feet high, and travelers must scurry to the higher land for safety, warned by the sound before the water is seen

Returning to Atocha and Uyuni, I went out by the way of Antofagasta, Chile There are now three ways of getting to La Paz by rail, Mollendo through southern Peru, and crossing Lake Titicaca, as previously described; Arica through the disputed province of Tacna, and Antofagasta to Uyuni as just mentioned. When the road is finished from Atocha to La Quiaca there will be direct communication by rail from Buenos Aires to La Paz.



A WOOLLY-TIPPED COLUMNAR CACTUS



THE CARDON, A COLUMNAR CACTUS
Common in southern Bolivia. Boards for building purposes are made from the woody ring. This stem is about a foot in diameter.

The southwestern part of Bolivia through which our train passed is very arid with much alkali, what is often called in

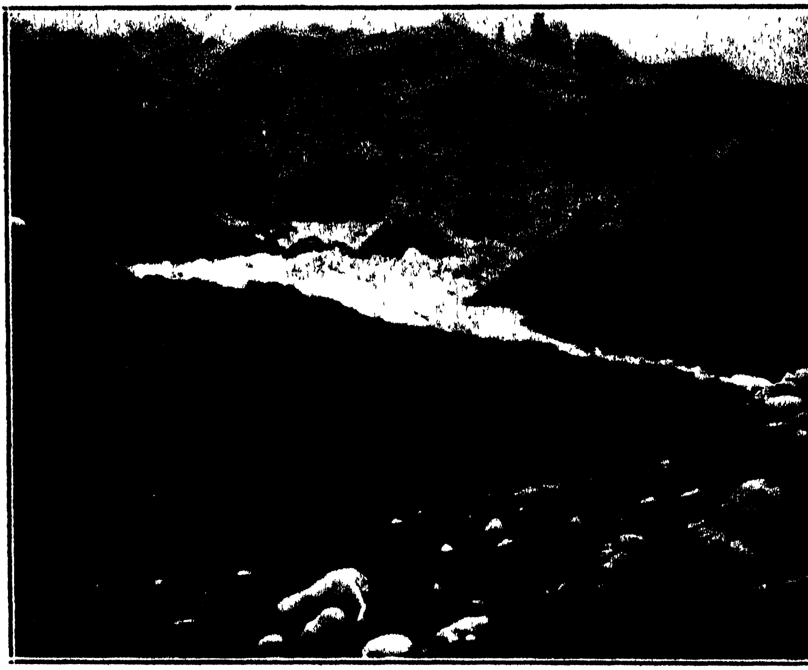
GORGE ON THE WAY TO TUPIZA, SOUTHERN BOLIVIA

LLAMAS AT ATOCHA, SOUTHERN BOLIVIA

our Great Basin region by the colloquial name slick desert. There is produced here much borax, salt and other minerals. The whole interior of western Bolivia is a great plateau, much of it 12,000 to 14,000 feet altitude. The valleys, especially toward the east and south, are rich agricultural irrigated regions.

The botanical results were of great interest and will ultimately appear as an account of the grasses of Ecuador, Peru and Bolivia, but are rather too technical for the general reader. I did not have time to go into the Beni, the tropical country to the north, lying in the Amazon Valley. Our knowledge of the flora of this region depends largely on the collections made by Dr. Rusby, of Columbia University, and his assistants, including Miquel Bang, and the staff

LLAMAS AT REST, ATOCHA



ONE OF THE GLACIERS ON ILLIMANI AT ABOUT 16,000 FEET

of the recent Mulford Expedition This northern area was formerly a great rubber-producing district, but the rubber industry in all South America has been injured by the product from the plantations in Malaysia

THE PHYSICAL BASIS OF DISEASE

By THE RESEARCH WORKER

STANFORD UNIVERSITY

VII. CURATIVE FORCES OF THE HUMAN BODY

"Now we've entered your state," said the manufacturer, as the Overland Limited was descending the western slope of the Sierras the next morning, "you'll probably want to spend your time boosting California."

"I'm not a 'Native Son,'" replied the research worker

"Congenital Californians are objectionable," said the lawyer "But, were you ever at the mercy of a native Texan?"

"The worst bore of them all," said the manufacturer, "is the booster of 'Little Ol'N'Yawk,' ignorant of everything west of the baby bluffs he calls the 'Glorious Palisades.'"

"We've taken up the main causes of human disease," said the research worker. "Congenital defects, tissue degeneration, tissue death, tissue overgrowth, accumulations of fluid, abnormal chemical reactions, psychical perversions. Let's take up as our topic the various curative mechanisms of the human body, forces tending to prevent or to overcome disease. The human body is really a wonderful structure. Adequate factors of safety, marvelous powers of readjustment and self-repair."

"What percentage of diseases will get well without treatment?" asked the lawyer.

"Impossible to say. Many diseases are self-limiting, full restoration of the body to its original power and efficiency without treatment. With most diseases, however, recovery is only partial without medical aid There is some permanent loss of capacity or efficiency. Only a small percentage of human diseases are incurable without medical or surgical treatment."

"One of the important defenses of the human body is the reserve capacity of vital organs. The major part of almost any organ can be removed surgically or destroyed by disease, and the organ will still be able to perform its necessary work—two thirds of the kidneys, half of the lungs, three quarters of the liver. Or

degenerative processes may attack an organ as a whole, reducing the power of its individual cells by half, even by two thirds and the organs still be competent to meet ordinary demands. Such an organ, however, may be incapable of meeting emergency demands.

"Not only is there this large reserve capacity of individual organs, but there are examples of duplication of function in different organs. Certain organs may be completely destroyed by disease with other organs capable of performing their necessary work. In rats, for example, the adrenal glands may be completely removed. Certain cells in other tissues will perform the necessary work The adrenal glands or their equivalent, as you know, are necessary for life."

"Another valuable defense is the growth potentiality of vital organs You are familiar with growth potentiality in muscles. By proper exercise the muscles increase in size and strength. Exactly the same growth potentiality exists in vital organs If the aortic opening from the heart, for example, is narrowed by tissue overgrowth, increasing the resistance to the forward passage of blood, the increased work necessary to keep up a normal circulation stimulates the heart muscle to growth The heart walls may become two or three times their normal thickness and strength. The reserve capacity of such a heart may be nearly equal to that of a normal heart."

"Is that what's meant by 'compensation'?" asked the manufacturer. "The doctor said my nephew would be all right as soon as his heart was 'compensated ' "

"The process is known technically as 'compensatory hypertrophy' or compensatory growth—increase in size and strength counterbalancing the increased resistance to blood flow. Compensatory growth is common to all organs and tissues. If one kidney of a dog is removed the remaining kidney will almost double in size within four or five weeks. This is a common surgical exercise for medical students. The major part of the liver may be destroyed and the liver restored to its normal size by growth of the remaining parts. It is not uncommon in rabbits, for example, to find all but one lobe of the liver absent or destroyed, with the single uninjured lobe as large as an entire normal liver.

"Compensatory growth of uninjured portions tends to restore a vital organ to its original reserve capacity. The restoraton is rarely complete, however. There is usually some permanent loss of ability to meet emergency demands. Certain organs even have

almost no growth potentiality. This is true of the brain. Destruction of one part of the brain causes no compensatory growth of the remaining parts.

"There are limits to this growth potentiality in all organs. If too large a part of an organ is destroyed by disease, the remaining parts may be so exhausted by overwork that compensatory growth does not take place. The uninjured parts may even degenerate or shrink as a result of this overwork.

"Can you stimulate this compensatory growth?" asked the lawyer.

"There is no known drug that will directly stimulate the compensatory growth of vital organs. Indirectly, the growth may sometimes be hastened by decreasing the necessary strain on the organ. Rest in bed, proper diet, elimination of waste products will sometimes reduce the necessary strain so that compensatory growth takes place. One of our valuable assets in this connection is our sense of fatigue. Reduced capacity in almost any organ may show itself in increased consciousness of fatigue. This tends to force the individual to adopt a mode of life consistent with the reduced capacity of the organ."

"There are equally important defenses not dependent upon the size and growth potentiality of vital organs, but dependent upon chemical factors. One of the most important of these is the food reserve or emergency rations in the body. You are familiar with the store of predigested and prepared fat that may be used as food in times of starvation or emergency. There is a similar store of predigested and prepared starches and sugars. By means of this store the percentage of sugar is kept fairly constant in the blood, even though no sugar or starch is taken as food. The blood, as you know, contains about one tenth per cent. sugar. A pound of predigested sugar is stored in certain tissues, particularly in the liver. Emergency supplies of other foods also exist.

"One of the most important emergency substances is the emergency supply of alkalies. Many of the commoner poisons formed by putrefactive or degenerative processes in the body or introduced from without are acids. A trace of free acid, as you probably know, will kill tissues. The emergency alkalies promptly neutralize these acids before they reach vital parts. Several ounces of vinegar, for example, must be injected into the blood stream of a dog before the reserve alkalies are used up.

"Equally important chemical defenses exist against other common poisons. Carbolic acid, as you know, is constantly being

formed in small amounts by putrefactive processes in the intestines. Carbolic acid is quickly rendered non-toxic by chemical defenses. Very adequate defenses exist against all the commoner poisons."

"What about eating yeast to stop intestinal putrefaction?" asked the manufacturer. "The papers are full of it."

"The advertisements I've seen have advocated yeast solely as a source of vitamins. There are certain chemical substances in green plants that are necessary foods. Scurvy, rickets or other partial starvation diseases may develop if one is deprived of these substances. There is an overabundance of vitamins, however, in ordinary diet. Milk, butter, lettuce, tomatoes, oranges are particularly rich in vitamins. Yeast also contains vitamins. If you prefer a yeast cake to a salad or a glass of milk, I see no reason why you shouldn't eat yeast."

"But the papers say yeast cures disease," insisted the manufacturer.

"The advertisements I've seen have been very cautiously worded. A rat on a vitamin-free diet has a stunted growth. Add yeast to his diet and he will grow. The advertisements don't say, however, that if you add any other source of vitamins, such as milk, tomatoes, lettuce, alfalfa, the rat will grow equally well, even better. The ignorant reader, of course, may imply that yeast is a cure-all."

"Clever sales method," said the manufacturer.

"But rotten business ethics. How about the ignorant consumptive who wastes valuable months eating yeast that should be spent in a sanitarium? Or the cancer that reaches an inoperable stage while the woman eats yeast?"

"Besides adequate chemical defenses against the commoner poisons there is a remarkable chemical potentiality against unusual poisons. Take morphine. The normal individual has a very rudimentary defense against morphine. Morphine is destroyed very slowly in his tissues. A morphine addict, however, rapidly destroys relatively large quantities of morphine.

"A better illustration is furnished by toadstool poison. The body has very rudimentary chemical defenses against this substance. A small quantity causes death. An animal, however, that is given repeated minute doses of toadstool poison rapidly develops his rudimentary defenses. Within a few weeks the animal can be given a hundred times the usual fatal dose of toadstool poison without apparent symptoms.

"This acquired resistance to toadstool poison has been carefully studied. Part at least of this defense depends upon chemical changes in the blood. A small amount of blood from a resistant animal, mixed with toadstool poison, will render the poison harmless. The mixture may be safely taken by normal animals. Even the clear serum or liquid portion of the blood has this poison-destroying or poison-neutralizing power."

"Is that serum ever used?" asked the manufacturer.

"The number of cases of toadstool poisoning is too small for such a serum to be commercially profitable. I am not aware that it has ever been tried with human beings. The popular fear of toadstools is an adequate protection. A somewhat similar serum, however, prepared by stimulating the rudimentary defenses against snake venom, has been tried. This serum has distinct curative effects if administered promptly after snake bite.

"The most important applications of such sera, however, are against infectious diseases. In diphtheria, for example, the usual death-rate of 40 per cent. has been cut down to less than 2 per cent. by anti-diphtheritic serum, a saving of life that can be effected in no other way. Unfortunately, sera have been found of no value in the majority of infectious diseases. Take tuberculosis, for example. Thousands of attempts have been made to produce a curative serum, thus far with no success. The essential chemical defenses against tuberculosis apparently do not exist in usable quantities in the blood. The essential defense is presumably located in some other part of the body. Just where, is unknown."

"Why don't you get on the job?" said the manufacturer. "Locate this defense."

"This problem is typical of numerous research problems now waiting solution. The average university research worker hasn't the equipment, technical assistance, leisure or funds for such work. The most he can do is to content himself with some minor, often unimportant, phase of such a problem."

"I should think the regents of any university would sell their shirts to make possible such research," said the lawyer.

"As soon as the importance of such work is realized by the general public, adequate support will undoubtedly be provided."

"Although sera have been found valueless in the majority of infectious diseases, other methods of using our rudimentary defenses have in some cases been successful. If toadstool poison were much more common, toadstool fragments being a frequent

contamination of daily food, it would probably be possible to protect an individual against this danger by developing his rudimentary defenses—repeated administration of minute doses of toadstool poison. Whether or not this would be effective one can not say. The defense might never become sufficiently high with human beings to protect against the ordinary accidental dose of toadstool poison. The defense might not be sufficiently lasting to be worth while. It is, however, possible that a very effective defense might be developed, after the administration of only two or three minute doses of toadstool poison, a defense lasting a lifetime.

"This method of stimulating our rudimentary or potential chemical defenses has been successful in a number of infectious diseases. The death-rate from smallpox, for example, has been reduced fully 99 per cent. by vaccination. Typhoid fever was almost eliminated from the army. A number of veterinary diseases have been controlled."

"Why is there such a violent objection to vaccination?" asked the manufacturer.

"The objection is mainly psychological—infantile resistance to authority, a prominent characteristic of childhood. With a few, however, there is a real objection due to religious belief."

"I have a neighbor of that kind," said the lawyer. "Retired minister. Divides his time equally between denouncing vaccination because it 'defeats the purpose of the Almighty,' and taking pills to assist the Almighty in relieving his constipation."

"Unfortunately this method of stimulating the rudimentary defenses has been found of no value in the majority of infectious diseases. Tuberculosis and syphilis are examples. In neither disease can the rudimentary defense be sufficiently increased by vaccination to afford any degree of protection. A successful method of anti-tuberculous vaccination, however, has been found for cattle."

"Then we may expect, in time, a successful method for human beings," said the lawyer.

"I am not so certain of that. The rudimentary defenses of cattle against tuberculosis are much more efficient than those of human beings.

"Development of the rudimentary chemical defenses is the main way in which the body automatically overcomes infectious disease. Within a few days after receiving an infection the rudimentary chemical defenses are often sufficiently increased to kill the invading micro-organisms or to render them harmless. This automatically increased chemical defense is occasionally permanent, lasting a lifetime. It is often transient, however, disappearing within a

few days or weeks. Gonorrhea, for example, even when spontaneously cured, leaves behind it no increased resistance to reinfection."

"Can you hasten the development of these defenses?" asked the manufacturer.

"Direct stimulation of the potential chemical defenses by therapeutic agents is a research goal for the future. We are too ignorant at present of the physiological mechanism of these defenses to make direct stimulation possible. Physicians must rely on indirect methods."

"Osteops claim they can do it," said the lawyer.

"Massage is a valuable therapeutic agent. It's used by all schools of medicine. It is particularly valuable for its psychical effects. There is no evidence, however, that massage in any of its forms will directly hasten the development of our potential chemical defenses. I doubt if osteopathic physicians make such a claim. It is easy to misunderstand their figurative language."

"How about Christian Science?" asked the manufacturer.

"There is no experimental or statistical evidence that the development of the rudimentary chemical defenses can be directly assisted by any form of religio-therapy. The blood of the most ardent Christian Scientist will not render toadstool poison harmless for an experimental animal. Nor will his tissues or body fluids kill and digest more germs of syphilis than those of the average individual. The death-rate from influenza among Christian Scientists is the same as that among his irreligious neighbors. Remember, we are not dealing here with subjective sensations, the psychical side of human disease."

"Then you do claim there's no God," said the lawyer.

"My statements were statements of biological facts. They are not inconsistent with any conception of Deity with which I am familiar.

"The two groups of defenses we have considered: first, the reserve strength and growth potentiality of vital organs, second, the chemical reserves and chemical potentialities, are the two most important groups in the human body. There are a number of valuable minor defenses, however. Among these are—

"Brush y' off, suh?" said the porter.

"Sorry to break up the party," said the lawyer, "but I get off at Sacramento."

RELIGION AS A FACTOR IN HUMAN EVOLUTION

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PERFECT men in a perfect environment is the final aim of all human endeavor. But we are facing a dilemma. One of the many attributes of the perfect man is that he should grasp all truth. Present-day knowledge is but a small fraction of the total truth, discovered and undiscovered, and there are few if any men who have either the training or the mental capacity to master completely and in detail even two or three of the departments of knowledge out of the scores of departments in which modern research is rapidly increasing the total human knowledge. Furthermore man can not be trained or educated up to such a point. Heredity will not permit it, but, pointing now here, now there, it says to each man, "Thus far, and no further, shalt thou go." Thus is man limited, not only in this, but all other attributes of perfection, such as bodily perfection, resistance to disease, moral beauty and ideal temperament There is a religion which bids man to be perfect, and tells him that the first and most important thing for him to seek is the kingdom of God and His righteousness; and this kingdom and this righteousness imply nothing less than a perfect race of men in a perfect environment. This is just what we stated at the outset to be the final aim of all human endeavor.

Historians and psychologists have told us much about the origin of religion and its effects upon man in the past. It would be interesting to run over the leading facts and theories, if such were possible within the space of this article, and at the same time give an epitome of the whole of human evolution to the present day—a thing no mortal yet can do—but it is my purpose here to confine attention to what is equally interesting and far more important: man's *future* evolution as it may be affected by the religion factor. The past of evolution is always interesting, chiefly so because of the light it throws upon the course and method of evolution in general, and what we may expect in future.

Several keys must be applied simultaneously if we would unlock the safe-deposit drawer which guards the future perfect men. Heredity is one of the indispensable keys, as are also ideal training and ideal surroundings. The result will be perfect men in a perfect environment. A certain religious factor is, however, essential

to each one of the three keys just mentioned—heredity, training, surroundings. But there are at least two classes of people who can see no logical place for religion: first, those who have had little or no religious training or experience, and who therefore can not be expected to see anything in it; and secondly, the many who have been unfortunate, in one way or another, in the religious experience they have had, and therefore shun it. Some would add to these two other classes: thirdly, those whose heredity omits entirely religious sentiment, and fourthly, those who, as followers or admirers of some in one of the first three classes, take their word for it that there is no logical place for religion in an enlightened world. Right here we may well focus on our dilemma mentioned at the outset—a world full of knowledge which is only a fraction of the sum total of truth, discovered and undiscovered, also full of people of varying capacities to grasp limited portions of said fraction, and, furthermore, able to measure up to only a part of each of the other characters or attributes of perfect men. The religious deficiencies just mentioned become inextricably confused with the mass of other deficiencies. The perfect men must be produced, and the surroundings must be perfected; how are we to proceed?

At once there come to mind schemes to educate the world of mankind in the principles of eugenics, that they may apply these in their home life as well as in their selection of mates. More radical plans, breaking up more or less completely the long-sanctioned home ties, have been proposed. Numerous social or religious colonies have been founded with a view to bring utopia or revive the golden age. One system of education has criticized and supplanted another toward this end. One religious denomination after another has arisen to point out the weaknesses of other systems, and bring the perfect creed or practice. Men have even gone to war to reduce slavery or to make the world safe. But the old world remains very imperfect and man very far from his goal. Man has greatly multiplied the *things* which he possesses, and his knowledge has far outstripped his individual capacity to absorb it. His heredity appears to remain about the same as yesterday or a bit lowered through his own interference with nature's processes for eliminating the weak and the mentally unfit and the emotionally unfit. These two latter classes, comprising most of the criminals, were doubtless quietly put out of existence by their fellows of more barbarous or savage days. So much for our present heredity. As to our surroundings, we are indeed learning some things about bettering this world, improving its fruits, vegetables, grains and domestic animals; inventing labor-saving devices, means of transportation and communication; yet much of our labor saved was first brought about by the things and circumstances which we ourselves had

made, while in many other respects we have marred the beauties of nature and polluted the air and the waters. The chief difficulty in educating all mankind to the point of practicing eugenics would lie in inducing people with such limited minds as the average man possesses to want to try it. It could be properly planned and would work very well if they would all be willing to apply the fundamental principles. A group of geneticists to-day could very easily draw up a brief and simple statement of the natural laws underlying race-improvement, in such form that all possessing average intelligence could understand and follow if they would. But how many would follow them? The least fit, upon whom the restrictions would fall most heavily, would be the least apt to submit. Another constitutional amendment, of world-wide application, would be required to control them. And yet it pays to meditate upon such plans, for a way may yet be found to uplift the human race as a whole.

A plan in which more immediate hope would seem to lie is suggested partly in the famous Hebrew historical literature and partly in the record of rocks, which reveals something of the story of the succession of creatures which lived in the past. We may call this the New Abraham Plan. Paleontology shows us that single individuals, or single pairs, have been the starters of new species, rather than great masses of individuals. The plan which was laid down for Abraham, and conceived by him, would have produced a new species of superior human beings if it had been consistently and unfailingly carried out. Even as it is, with all their breeches of the original sacred plan, the Jews are a remarkable people, decidedly distinctive in many ways, if not altogether in the ways originally planned. They came very near to producing a new and distinct human species, and although they fell short, they have pointed the way in which it can be done. Any one may deliberately determine that he will be a new Abraham, and that he, and his family after him, shall establish a new race, superior in every respect. If this man's predetermined principles were as lofty and as pure as those laid down for the Hebrews, and if they were consistently carried out by his offspring, under pain of expulsion, the result would be very marked, and, I believe, surprisingly speedy. This human race is more primitive and plastic than people generally suppose. The great masses of the people labor under the delusion that we are inextricably fixed in a rut—that as we are now, so we always have been and always shall be. But one of the hopeful things which zoology points out about our race is that it is not yet so highly specialized as not to be able to change and continue changing.

The plan proposed for Abraham and his descendants involved pure line breeding, with careful selection of mates, and a code of ethics highly moral, sanitary and religious. The intense faith in the guiding supervision of God, the Creator of all things, was a support without which the plan never would have been carried out to such an extent and during so long a period of time. Man is essentially a religious creature and can do things with the aid of religious fervor and faith in which he never would persist without such religious impelling force. It is bred in the "bone," and is as much to be taken into account as his appetite, affections and intelligence. In the Hebrew historical account we read that God said to Abraham "I will make of thee a great nation, and I will bless thee, and make thy name great; and thou shalt be a blessing: and I will bless them that bless thee, and curse him that curseth thee: and in thee shall all families of the earth be blessed. . . . I am the Almighty God; walk before me, and be thou perfect. And I will make my covenant between Me and thee." The conviction of such a covenant as this was a strong, guiding force in the life of a man like Abraham. When it came time for his son Isaac to wed, Abraham would not consider his marrying any of the Canaanites close around them, but insisted that a trusted servant go far back "unto my country, and to my kindred, and take a wife unto my son Isaac." Divine guidance was also sought in the selection of the relative who was to be Isaac's mate. And this same mate was later very careful concerning the mate for her own son Jacob, for we read: "And Rebekah said unto Isaac, I am weary of my life because of the daughters of Heth: if Jacob take a wife of the daughters of Heth, such as these which are the daughters of the land, what good shall my life do me?" Isaac thereupon commanded Jacob to go back to the old ancestral stamping ground, and find a cousin to marry. And always there was the religious conviction of the presence and guidance of God through this eugenic scheme.

In spite of many individual errors, shortcomings and even failures, many very capable and brilliant men were produced from this stock, such as Joseph, David, Solomon, Daniel, Isaiah, Jesus and Paul, some of whom were remarkably pure in their moral strength, while others showed weak traits along with their very eminent qualities, for the whole scheme had not provided sufficient weeding-out of the morally weak or dishonest. Such undesirables, together with all backsliders, should have been promptly sent out of the community and merged in the Canaanites. What wonderful beings David and Solomon would have been, if they had been as consistently pure in heart and as consecrated as Joseph, Daniel and Jesus. It remained for the latter to embody all wisdom and virtue and faith.

The forerunner of Jesus saw the need of more housecleaning in the whole eugenic scheme, and clearly stated the principle of the axe and the fan, a principle which many weaker-kneed followers can not bear. He believed one wasted his time in pruning a tree or a man with bad heredity. Not the pruning-hook but the axe is needed, and that to be applied right at the root. There was no place for the man or the tree which would not bear good fruit. Similarly the fan was to separate the bad from the good. The bad tree and the chaff alike were to be promptly and completely destroyed, as by fire; the good trees cared for and the wheat gathered into the garner. Our social work of to-day is doing undeniable good, but also much good time and effort is wasted trying to prune human "thorns" into "fir trees" and human "briers" into "myrtle trees." Long before the days of John the Baptist, Isaiah had sensed the hereditary principle, and prophesied: "*Instead of* the thorn shall come up the fir tree, and *instead of* the brier shall come up the myrtle tree." Recognizing the same principle, Jesus later said, "Ye shall know them by their fruits. Do men gather grapes of thorns or figs of thistles? A good tree can not bring forth evil fruit, neither can a corrupt tree bring forth good fruit. Every tree that bringeth not forth good fruit is hewn down and cast into the fire." This is directly in accord with the forerunner's famous principle of the axe and the fan, "And now also the *axe* is laid unto the *root* of the trees: therefore every tree which bringeth not forth good fruit is hewn down, and cast into the fire." Referring to Jesus, the forerunner says, "whose *fan* is in his hand, and he will thoroughly purge his floor, and gather his wheat into the garner; but he will *burn up* the chaff with unquenchable fire." This can not possibly be made to mean everlasting punishment; it is, however, very good eugenics. Whatever destruction there is is very prompt and effective. The innately bad is separated and *burned up*. If there be anything of the doctrine of divine election in this eugenic principle, it is very simple and intelligible. Those who find this teaching of Jesus and his forerunner hard to understand either fail to grasp its simple truth, or fail to see the beneficent healing in the mildly bitter dose. Segregation and consequent elimination of undesirables of every class is one of the most helpful measures applicable to our race. Jesus also had no use for foolish people, as shown in his parable of the foolish virgins, nor for faithless folk, as shown in his condemnation of Pharisees. By eliminating every class of undesirable the race is rid of its heaviest handicaps, and is able to progress on its upward road unburdened.

From the birth of Abraham to the giving of the Ten Commandments about five centuries passed. Therefore five centuries before the giving of the Ten Commandments we find a man with surpris-

ingly high moral purpose for his times and an even much more surprising clarity of vision and mental acumen. From the call of Abraham to Joseph's Egyptian experience was about two centuries. In this short time we find a direct descendant of Abraham more highly developed morally and with as good or better mentality and vision and faith. Joseph was nearly three centuries before the time of the Ten Commandments. Five centuries after the Ten Commandments King Solomon, world-famed for his wisdom, is ruling over the offspring of Abraham. His educational advantages were vastly greater than had been those of his illustrious ancestors of ten centuries back, and these, together with his superb mind and other God-given, hereditary qualities, made him a type for wisdom, glory and power through succeeding ages, so much so that many of the descendants of Abraham looked back to the reign of Solomon with wistful longing. But we have a right to expect more moral strength and a higher code of ethics five centuries after the Commandments and eight centuries after Joseph. The Israelites had not been faithful to their long-guiding principles; they had mingled with their surrounding neighbors of lower ideals and inferior lineage; had even taken such into their midst and merged them with themselves; had not strictly kept the Ten Commandments given them nor winnowed out from their midst the black sheep or backsliders, who would not or could not be faithful to their code and live the clean, noble life of wisdom and faith and observe the care in the choice of a mate, thus following the example and precepts of the wisest of their forefathers.

If from Abraham to Solomon this purity had gone hand in hand with the winnowing process during all the ten centuries of time, a far more wonderful heart and mind and personality would have been born into Solomon. He would have been arrayed more gloriously than the lilies of the field, not less so.

Between the reign of Solomon and the ministry of Jesus another ten centuries elapsed, and we find at last a man possessing all the excellencies of an Abraham, a Joseph, a Daniel and a Solomon, with none of their deficiencies, but many added virtues, shining bright in the glory of the Father, the All-Great Creator. At last the plan of Abraham and the plan of the Ten Commandments showed full fruition in one man among the millions. And he taught the imminence of the kingdom of heaven. That all-perfect environment, peopled with its all-perfect men, was right at hand where we may grasp it, if we but exert ourselves bodily and mentally to that end. If we let the principles of the axe and the fan and the Ten Commandments and the Golden Rule and the Sermon on the Mount have full sway in our personal life, our social life and our corporate life, which includes both our business organizations and our polit-

ical and national organizations, then indeed would the ideal men in the ideal environment soon be here upon earth to stay as long as life lasts on this sphere. The Kingdom of Heaven would be upon earth.

The genetic principle of selection and rejection, which some holy fathers have seen through a glass darkly in the form of a doctrine of divine election, and which we, using the symbolism of John the Baptist and of Jesus, may well call the principle of the axe and the fan, was foreshadowed in the plan of Abraham. Abraham and Joseph and the great prophets of Israel were men of vision. Their Maker revealed to them fundamental truths of Nature. They saw, as it were in a vision, certain underlying laws of life. How sharply some of these men drew the lines; and how hotly some of the prophets upbraided the people for their waywardness and their folly! And in more recent times, a holy monk and a teacher of youth, named Mendel, experimenting scientifically in his garden laboratory, revealed by scientific method, to the world of modern investigators, the way which is rapidly leading to an understanding of the basic principles of heredity and to a comprehension of its inevitable importance.

To-day in the city of Cincinnati there is a man of vision named Nash, a manufacturer of men's clothing, who, sensing that the Golden Rule is the divine law governing human relationships, incorporated it into his business in 1917, with apparently miraculous results in the years which have followed. These results affected the business, the employees and himself, with remarkable benefit to all, both in times of adversity and time of prosperity. From several years' experience Mr. Nash is convinced that the Golden Rule is "the only infallible, workable industrial and economic law." Many men of vision in the past have glimpsed portions of the truth, but few have actually incorporated such a vital truth into modern business on such a grand scale and in such a vital manner. Nash has shown the world that there is a vast difference between letting every one tacitly accept the theory of the Golden Rule and actually making it the fundamental rule of a business employing thousands of persons. Any new hand coming in to such a business, though he may never have heard of the Golden Rule before, soon realizes that he is surrounded by its atmosphere and becomes influenced by it as by a force which he can not resist.

But the Golden Rule is only a small fragment of the Sermon on the Mount. It is found in the twelfth verse of the seventh chapter of the gospel of Matthew, while the Sermon on the Mount fills the fifth, sixth and seventh chapters of Matthew. And I believe that in order to be able to apply the Golden Rule one must know more than the Golden Rule, in fact be thoroughly steeped in all the basic

principles of the Sermon on the Mount, besides being thoroughly the master of his own business in which he would apply it.

Now, into what sort of beings would we have this race of ours evolve? Creation is but an ugly mess if we are to remain as limited in intelligence, as cramped in mental capacity, as faulty physically, and as ordinary and joyless in personality as we are at present. God would have done but a bungling job in making man if we can not become innately vastly superior to what we are. Even the best men this world to-day can show are little more than puppets, jokes or suggestions of what men should be.

One thing is certain, the man of the future, when perfected, must be a tremendously joyous individual;—none of your mechanistically developed, shrewd, coldly calculating brains, requiring that all be done for him by machinery, while he thinks, and just thinks, and then thinks again, with perfect precision, accurately and unfailingly. Neither is it desirable that he become just a cog in some vast social organization. He must always be individualistic, and should remain sufficiently primitive to be able to get his own food from nature by his efforts. The sequence of living forms throughout the dim corridors of the past, as shown in the fossil record of the rocks, points out too clearly the dangers in too high a degree of specialization. Our brains, even in their present stage of development, are continually tempting us to neglect our bodies and depend solely upon the cleverness of our minds for our life and sustenance. A certain measure of physical degeneration in consequence of this is manifesting itself fairly generally to-day. We want our bodies to be stronger and more generally beautiful in form than they are to-day. We want them to be thoroughly resistant to all diseases, a hereditary quality to be borne in mind by our new Abraham and his successors in their choice of mates, as also in their expulsions from the clan or restrictions within the clan. Many important methods are being pursued in the prevention of disease and in rendering man more resistant to various diseases. The most desirable of all these methods would be to be born absolutely immune to disease. Hereditary immunity is better than resistance, either acquired or hereditary.

Our perfect man of the future, then, should be a highly joyous individual, with far greater mental capacity than any man now possesses, a strong, quick and well-formed body, immune to disease. What *else* does he need?

In order to attain that degree of joyousness, and the mental and physical perfection which are essential to the joy, he requires the truest type of religion which heaven or earth can yield. Startle not at the word *religion,* at which many conjure up mental pictures varying greatly from the fundamental religion of Nature, which

pervades all the Universe! Our new Abrahams, if any wish to be such, must have *vision*—mental and spiritual vision or faith as it is often called, and they must have a law or code by which to go, for all nature has its laws. And the world has not seen a better code of ethics than that given by Jesus in the Sermon on the Mount nor a better faith than that perfectly natural faith which we find in Abraham and in Joseph, Moses, Daniel and developed to its highest degree in Jesus.

All things in nature have a physical and chemical basis, but pure physics and chemistry, raised to the nth degree in the evolution of the finished man of the future, would leave him a cold, joyless and unenviable mental and physical machine at most. We may define religion as all that which, added to pure physics and chemistry, would make the men of the future radiantly beautiful, joyously creative and give them the highest degree of moral and spiritual vision. This definition of religion is a very different one from what comes to the minds of many, but when carried through, it implies the strongest and most abiding faith in God, and in Jesus, the Savior and the giver of the perfect code, the Sermon on the Mount, which embodies the combination of eugenics and Christianity necessary to guide the life of any who would be a new Abraham through whose coming generations the people of the earth would be blessed.

Any one, of any race, may be an Abraham, who has the vision and faith in the Great Guiding Power and the requisite moral, mental and physical virtues, and the clear and distinct laws by which to guide his conduct and the conduct of all his growing clan. His clan would in time, by sheer superiority, o'ertop all other peoples of the earth in every desirable aspect. Whatever of beauty he found, in mountain or flower or stream or sunrise or star or living being would be his by right and would enter into the personality of his people. The Kingdom of God and His righteousness would be his world in which he lived while on earth and his heaven after death. In the light of God he would see light and in an earth made over new he would prepare for heaven, be it in some far-off universe, or be it everywhere, as God is everywhere, or be it both.

The plan of Abraham is as simple as nature itself, whose deepest laws it involves; and it is as sure as physics and chemistry through which God works, for any who will consistently follow it through the generations, a thing which the descendents of the old Abraham have done but faultily, very faultily. It is equally the plan of Jesus, the plan of nature, and the plan of the Kingdom of God and His righteousness. It leads to ideal men in ideal surroundings, men and surroundings of a beauty and lustre and brilliancy and joy and wisdom beyond our highest conceptions.

SEASONAL PREVALENCE OF DISEASE

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PERIODICITY is one of the interesting phenomena in epidemiology, and a more searching study of the causes of the cyclic tendency of disease discloses fundamental factors of vital importance. A number of the communicable infections tend to periodic recurrence, but very few diseases recur with sufficient regularity to predict their reappearance with any degree of certainty. Prophecy is a test of the soundness of science. Furthermore, to be able to foretell gives opportunity for preparedness and prevention.

We know that another pandemic of influenza will some day sweep the world, but we can not tell when this plague may recur. The intervals between pandemics have been quite irregularly spaced. Brownlee, however, has pointed out that after a pandemic of influenza, recurring waves appear at intervals of thirty-three weeks, provided the thirty-third week does not fall between June and December; if so, the recurring waves appear in multiples of thirty-three weeks, in other words, avoiding the warmer months of the year. This sequence was largely true following the last two great pandemics, 1889–1890 and 1918–1919.

Measles is an example of a disease that recurs cyclically and with considerable regularity. In endemic regions, epidemic exacerbations recur every two or three years. In large cities, the interval is usually two years, and in smaller communities, three years. The explanation of this rapid tempo in the recurring beats of measles appears to depend upon the accumulation of a new crop of susceptible children.

Infantile paralysis in Massachusetts displays a sort of regularity in the tendency to an excessive prevalence about every fourth season. These epidemic recurrences are followed by a gradual decline until the next period, as shown by the following figures:

Year	No. of Cases
1909	923
1910	845
1911	260
1912	169
1913	861
1914	151
1915	185

Year	No. of Cases
1916	1,926
1917	174
1918	99
1919	66
1920	696
1921	233
1922	217
1923	221

A study of these figures shows clearly the tendency of infantile paralysis to occur in periodic phases or pulses in Massachusetts. It seems curious that this same periodicity is not evident in other places and therefore does not appear to be a general rule. The Massachusetts figures, then, may be only a coincidence, although they indicate a definite tendency which appears to be part of the natural history of the disease in this state. Despite the vagaries and uncertainties of infantile paralysis, we know that as long as the disease prevails there will be more of it in the summertime than during the cold season. We can forecast its tendency to seasonal prevalence, but we can not tell how much of the disease will occur. In other words, while we can prophesy the nature of the curve, we can not forecast its magnitude. The amount of infantile paralysis is capricious and depends upon variables, which will be discussed under the causes of seasonal prevalence.

A good instance of the uncertain way in which epidemic diseases recur is shown by the visitations of plague in London from 1563 to 1680. In 1563, an epidemic causing 23,000 deaths was recorded. In 1603, London was visited by a severe epidemic. The disease then became quiescent and probably endemic for 22 years. Suddenly, in 1625, there was a devastating outbreak with upwards of 35,000 deaths. Following this, there was a long period of 40 years during which plague smouldered with two epidemic exacerbations, one in 1636 (10,400 deaths) and the other in 1647 (270 deaths). After 1647, the disease apparently disappeared, although in all probability it remained endemic, for it is easy to understand how occasional sporadic cases might be overlooked. In 1664–65 the Black Death in London carried off 68,596 of a population then numbering about 500,000. A graphic description of this epidemic is given by Defoe in "A Journal of the Plague Year." Numerous references to the disease will be found in Pepys's Diary. Benvenuto Cellini describes his own case in his autobiography. Plague is one of the diseases that stamped itself upon art, science and literature.

It is interesting and even instructive to speculate why bubonic plague in London became severely epidemic five separate times at irregular periods—1563, 1603, 1625, 1636 and 1665. Before plague can become epidemic, there must be a large number of complex variables in conjunction. We can not have an epidemic of plague without first having an epizootic in rats. At the same time, the fleas must be numerous and active and the opportunities for contact and transmission between rats, fleas and man must be close, frequent and favorable. When we realize that it is well-nigh impossible to cause an epizootic among animals in their wild state,[1] we can understand that a great number of factors determine the prevalence of the infection among the rat population. Furthermore, a severe epidemic of this sort leaves immune a large proportion of both rat and human population, so that another serious outbreak must await inflammable material. In view of the large number of factors and the number of complex variables that enter into an epidemic of plague, it would indeed be passing strange if a disease of this sort had any regularity in its periodic recurrences.

Plague is one of the diseases that profoundly affected the economic, political and social history of civilization. I happened to be in Stratford-on-Avon on July 11, 1914. I turned back the pages of the parish register 350 years, and found recorded on July 11, 1564, the death of one Olivarius Gunne, apprentice of Tomae Gather als Degge. Then followed this laconic statement—*Hic incipit pestis.* Up to this time, from three to five deaths (a month) were recorded in the parish register, but from July 11, 1564, the rate jumped as follows:

July 11–31	16	deaths
August	35	"
September	83	"
October	58	"
November	27	"
December	18	"
January	5	"

Two hundred forty-two deaths in six months is a heavy toll for the little vicarage of Stratford. Shakespeare was a baby three months old when the plague broke out. Judging from the names recorded, the infection swept away entire families. Fortunately not a Shakespeare is on the list. How much has mankind lost throughout the world's long history by the untimely death of genius on account of preventable infections!

[1] The failure to cause an epizootic among the rabbits of Australia is an illustration.

Another example of irregular periodicity is shown by the story of diphtheria epidemics in Boston, New York and Chicago. In Boston, diphtheria was epidemic in 1863–64, 1880–81, 1889–90 and 1894; in Chicago, in 1860–65, 1869–70, 1876–79–81, 1886–87 and 1890. Within recent years, such epidemic outbreaks have not taken place and the disease should never again be allowed to get out of hand.

Many other instances of the periodic recurrence of disease could be cited, but the burden of this paper is to discuss that form of periodicity which expresses itself in seasonal prevalence. Many diseases recur annually with the regularity of the perennials. Some endemic diseases are as constant as the evergreens; some are as sure as the thistles, daisies and goldenrod; some prefer the spring, others the autumn; some are like exotic plants that will not grow at all on our soil; and still others flourish only when imported.

Seasonal prevalence is one of the most characteristic and alluring studies in epidemiology. Many correlations are disclosed between climatic factors and the seasonal fluctuations of certain infections. These correlations do not prove causation; in fact, the more seasonal prevalence of disease is studied, the more mysterious do the causes become and the more complex the difficulties. There are many underlying influences which control seasonal prevalence other than the evident factors of weather and climate. The surface of knowledge has been only scratched—rewardful results await the searcher in this field; all of which adds zest to the pursuit.

The relation of season to disease clings tenaciously in common speech. "Catching cold" infers the influence of low temperature, and "summer complaint" connotes the effect of high temperature; "under the weather" implies the consequences of climate; the term "influenza" signifies a mysterious influence and even supernatural effect of our environment.

Many diseases have a seasonal curve of extraordinary regularity. They return year after year with the definiteness of the crops. However, seasonal prevalence of disease may to a certain extent be violated when a communicable infection is introduced into a virgin population. Thus, measles, influenza and smallpox do not always wait for cold weather when introduced into the South Sea Islands or into a concentration camp recruited from country districts. Susceptible material of this kind may catch fire and burn freely out of season. On the other hand, when certain of the contact diseases that prevail especially in the wintertime are introduced into the tropics, they have a tendency to die out. Scarlet fever has never gained a foothold in tropical countries, and measles and diphtheria do not become serious problems under a vertical sun. Contrariwise,

common colds, influenza, pneumonia and tuberculosis play havoc in warm and tropical lands, just as they do in temperate zones.

One must be unusually conservative in drawing conclusions concerning the incidence of disease in tropical countries, for morbidity and mortality records are imperfect enough at best in favored climes; they are particularly incomplete under tropical conditions. We are therefore thrown back upon personal experience and impressions: the former is limited and the latter may be misleading. I well remember some years ago that upon my first residence in a subtropical country, the existence of typhoid was dogmatically denied, for malaria was then the dominant diagnosis. We now know that typhoid fever is favored by warm weather and that this disease has long prevailed as a serious problem in tropical and subtropical lands.

As a rule, most diseases that have a seasonal prevalence show that this is more than a fortuitous tendency; indeed, is a distinct part of the natural history of the disease. The peak of the curve of many seasonal diseases follows the latitude. Just as blossoms come out two or three weeks later in Boston than in Baltimore, so also the seasonal diseases are often several weeks later in Boston than in Baltimore. The effect of latitude is striking and significant. In the southern hemisphere, the season for plant life and the season for disease prevalence are alike reversed. Sometimes it is not so much the month of the year as the condition of the weather at the time which influences disease prevalence. Thus, rheumatic fever reaches its peak in March and April in the United States, but in September and October in England; both these seasons are the damp changeable times of the year.

Among the various uses of a study of seasonal prevalence is the light it throws upon the mode of transmission and other factors concerning disease, especially a disease about which our knowledge is unsatisfactory. Take infantile paralysis as an example. The prevailing opinion among public health administrators is to regard this disease as a contact infection spread by means of the discharges from the mouth and nose. Abortive and missed cases and also carriers are believed to play an important part in its spread. Infantile paralysis has a very distinct summer prevalence. Cold weather outbreaks are comparatively rare occurrences, and in this country represent almost invariably the tailings of a previous summer epidemic. The disease normally reaches its peak in August and September and usually declines sharply with the coming of cool weather. Furthermore, infantile paralysis has a predilection for rural distribution and other epidemiological factors which run counter to the epidemiology of diseases spread by contact.

A closer study of the seasonal prevalence of infantile paralysis shows that while the disease recurs with great regularity every summer, the curve is not a simple curve. A study of the seasonal prevalence of this disease by Dr. W. L. Aycock and Dr. Paul Eaton[2] in my laboratory has disclosed the fact that, preceding the summer peak, there is a minor rise which takes place in the spring. In other words, there is an increase in the number of cases about March and a subsidence in April and May before the definite rise which occurs in June up through July and August, to decline with the cool weather of September. Thus, the seasonal curve of infantile paralysis is bimodal. The significance of this is not clearly evident, but indicates that the disease is spread in more than one way, one factor being operative to cause the minor spring rise and other factors being responsible for the summer peak. A similar study of the curve of typhoid fever shows it also to be bimodal, thus lending countenance to the hypothesis that infantile paralysis may have several methods of spread.

Epidemics of pneumonic plague are restricted to northern climates and occur especially in cold weather. The Manchurian epidemic of 1910 occurred during the winter and was one of the most virulent epidemics of modern times, the case fatality rate being over 90 per cent. A limited outbreak, due to an infected squirrel, occurred in California in 1919. Bubonic plague occurs in the summertime and has an entirely different epidemiology. So far as seasonal prevalence is concerned, the pneumonic form of the disease follows the general rule of respiratory and contact infections, while the bubonic form runs true to form of the insect-borne diseases.

A number of diseases show two peaks, one in the spring and the other in the autumn. This is frequently the case not only with the acute respiratory and throat infections, but also with tuberculosis, nephritis and rheumatism, as well as neuroses, which may have a higher peak in the autumn than in the spring. The causes of biseasonal prevalence are not at all clear.

Seasonal prevalence is wrapped up with geographic distribution and is one of the underlying factors in the distribution of disease over the earth's surface, for the reason that seasonal prevalence naturally becomes a function of latitude. In general, diseases of the respiratory tract flourish in the colder regions, whereas in the warmer areas intestinal infections and parasitic fevers are apt to prevail.

Huntington's book on "Civilization and Climate" reawakened stimulating and suggestive studies upon the way in which climate

[2] *American Journal of Hygiene*, in press.

controls human progress through its direct influence on health. Civilization has shown its greatest advance in the temperate zone. In a second publication, "World Power and Evolution," Huntington analyzes the effect of temperature and humidity on the death rate by means of climographs. He states that the climate which is ideal for the stimulation of human progress is one in which the mean temperature does not fall below a mental optimum of 38° F. or rise above the physical optimum of 60–65° F. This ideal climate must have variability, from say 19° F. in the coldest month of the winter to 73° F. in the warmest month of the year. A uniform climate becomes monotonous; variability is stimulating and important. Huntington uses cyclonic storms as an index of variability, assuming twenty such storm centers a year as an optimum. Relative humidity is also important, the extremes of humidity and dryness being unfavorable. Within these limits moisture seems more favorable than dryness.

We know that the physical condition of the air about us has a greater influence upon our well-being than its chemical composition. A warm, still, humid day is enervating and causes a rise in our bodily temperature; this also is responsible for discomfort experienced in a close, crowded and poorly ventilated room. In addition to the physical condition of the air, there are other factors that make up the sum total of weather and climate, so far as their effect on man is concerned. We are just learning the importance of sunshine and finding out that it is especially the powerful rays of short wave length that influence health. That we are responsive to our environment is clear. There are seasonal changes in physiologic activity. Mental, physical and emotional status vary with the weather and in part perhaps are influenced by it. The causes of seasonal changes in health and disease are varied, complex and largely undetermined.

Grouping of Diseases in Accordance with Seasonal Prevalence

The communicable diseases divide themselves naturally into three groups so far as their seasonal prevalence is concerned: (1) the insect-borne diseases, (2) the intestinal infections and (3) the diseases of the respiratory tract.

The Insect-borne Diseases

The group of diseases which are insect-borne prevail almost entirely during the summertime, that is, during the hot, moist season of the year, which is also the season of maximal activity in the biology of the insect vector. The insect-borne diseases give us the

best examples we have in epidemiology of endemicity and also the clearest cut instances of seasonal prevalence. We have no record of an epidemic of yellow fever in the wintertime. It is not conceivable that yellow fever could prevail in any district in the absence of Stegomyia calopus. Strange to say, we have a few curious exceptions to prove the rule. Thus, typhus fever prevails in the winter season and subsides with warm weather. This paradox is explained by the fact that lice are more common in cold weather and temperate climes than in warm weather and the tropics. The influence of temperature is well shown by the fact that typhus fever prevails in Mexico City but is absent in Vera Cruz. There is evidently something in the bionomics of the louse and perhaps in the cycle of the rickettsia bodies that makes cold weather favorable and warm weather unfavorable for the completion of the circle of events necessary to complete the chain from man to louse and back to man.

Even winged insects, which ordinarily are most abundant in warm weather and have their maximal flight in the summertime, sometimes cause winter outbreaks. This, however, can happen only when artificial conditions are provided. Thus, Mackenzie[3] reported an outbreak of malaria in southeastern Russia during the winter of 1922–23. The disease affected up to 90 per cent. of the population in many areas. The epidemic spread steadily throughout the winter with the thermometer varying from 20° to 30° C. below zero from November until March. The spread of the disease during the extreme cold appeared to be due to the fact that the drinking-water butt, combined with the almost tropical heat of the log houses of the peasants, afforded ideal breeding places for anopheles remaining in the huts from the summer. During the intense cold of winter, both the larvae in the water butts and adult anopheles in dark corners could readily be found in a large proportion of the peasants' houses.

The Intestinal Diseases

The seasonal prevalence of the intestinal diseases has a general resemblance to that of the insect-borne infections. Both normally have a warm weather prevalence. This is the case with typhoid fever, cholera, dysentery and the summer complaints of infants. The incidence and intensity of gastro-intestinal infections become greater as we approach the tropics.

While the curve of the intestinal infections shows a marked similarity to that of the insect-borne group of diseases, the one may be distinguished from the other by the fact that winter-borne

[3] *Lancet*, 1923, 55, 1225.

outbreaks of insect-borne diseases are unusual, whereas winter-borne outbreaks of intestinal infections frequently occur. Thus, "normal" or residual typhoid fever shows a marked summer prevalence and recurs in endemic centers summer after summer like an annual crop—provided there is a clean water supply. On the other hand, water-borne typhoid fever has a predilection for the winter season, when the water is cold. The vast majority of water-borne outbreaks of typhoid fever that have been recorded have occurred in the late fall, deep winter or early spring—avoiding the warm months. It is quite possible to tell from a glance at the seasonal curve of typhoid fever extending over a period of years whether water-borne infection is playing a serious rôle. When cities like Albany, Philadelphia and Chicago improved their water supplies, the typhoid curve was changed in two particulars—the rate was markedly lower and the curve of seasonal prevalence was reversed.

The year before last I encountered in Russia an interesting example of seasonal prevalence. Typhus fever was epidemic throughout the winter, declining in the spring and practically disappearing with the coming of warm weather. As typhus fever left, cholera appeared and increased during the summer, in turn to make place for typhus when the cool days of autumn arrived. The interesting part about this cholera outbreak was that so far as my investigations disclosed, it was quite independent of water-borne infection; at least no drinking water supply was infected on anything like the scale of the Hamburg epidemic in 1892. The summer cholera in Russia was a communicable infection in which water played a minor rôle, and its seasonal prevalence ran true to form.

The seasonal prevalence of bacillary dysentery and the diarrheas of children is quite constant in all parts of the world and correlates with the warm, moist, enervating time of the year.

Now that the summer group of intestinal infections has been largely controlled, the wintertime has become the unhealthy season of the year—at least in temperate climes. The greater morbidity and mortality during the cold weather dominates the total death curve in a country like the United States.

The Respiratory Group

The diseases of the respiratory tract have their maximal prevalence during the cold and changeable seasons of the year. This group includes, first of all, the acute infections of the respiratory tract, such as common colds, sore throats, bronchitis, influenza and pneumonia. Next, there is a group of epidemic diseases, the viruses of which are spread by the discharges from the mouth and nose,

which likewise have a preference for cold weather. This group includes diphtheria, scarlet fever, whooping cough, mumps, measles, cerebrospinal fever, smallpox, etc. While most of these infections have a predilection for the cold weather, it must not be inferred that they can not occur in warm weather. As a matter of fact, they all smoulder in sporadic fashion during the off season, which is probably the way in which they are kept alive. Furthermore, in addition to this occasional or endemic occurrence, many of these communicable infections break out in the summertime as veritable epidemics. Thus, we have occasionally epidemic outbreaks of common colds, measles, smallpox, influenza, etc., in warm weather. The tendency is well illustrated in the periodicity of influenza. Following an epidemic, the succeeding waves recur at intervals of thirty-three weeks; but, if this point in the cycle is reached during the summertime, the periodic expectation is apt to be missed or slight. If we may trust the records of the epidemiology of influenza, there are accounts of sixteen epidemics having occurred in the summertime. Despite these occasional and unusual occurrences, the respiratory diseases are clearly favored by the conditions accompanying cold, changeable winter weather and are deterred by the warm summer season.

The respiratory group of diseases is the most prevalent and damaging to which flesh is heir, and while they prevail more especially in temperate, cold and variable climates, they occur also in warm latitudes and even in the tropics. They are endemic everywhere. Epidemics are frequent and pandemics sweep the world like a devastating plague about once a generation. As a group, the respiratory diseases are less well understood and hence less controllable than the intestinal infections.

Another point of special interest in connection with this group is that the usual mode of spread is by contact and through discharges from the mouth and nose. The respiratory diseases, however, may also be transferred in many other ways. Thus, infection may be contracted indirectly in food and drink, by hand-to-mouth infection or by fomites, such as cups, spoons and other things that are mouthed.

Deaths from tuberculosis, cancer, diabetes and other diseases show a tendency to seasonal prevalence, despite the fact that these diseases in themselves are little influenced by season. This is due to the seasonal influence of the important complications of such chronic and debilitating affections. Thus, deaths from diabetes show a curve corresponding to that of pneumonia and bronchitis. The complications dominate the picture.

Another interesting factor in the cold weather prevalence of common colds, influenza, bronchitis, sore throat, pneumonia, measles, scarlet fever, diphtheria and a long list of diseases spread by the discharges from the mouth and nose is that in all this group contact infection is the main mode of spread. The spread of disease by contact implies close personal association. Close association favoring the spread of contact infections under poorly ventilated and crowded conditions is a concomitant of cold weather. In winter there is a tendency to huddle together; in summer, to spread out. Crowding, then, is believed to be a factor which accentuates the tendency to the seasonal prevalence of the contact diseases. On the other hand, it can not be the dominating factor, for we sometimes see these very same diseases occurring as sharp outbursts in the summertime, in the tropics and even under rural conditions. Influenza spreads like wildfire in sparsely settled country districts. A contact epidemic may break out at any season and once started runs its course in spite of weather or climate. Epidemics of smallpox and measles occur in the summertime. Gorgas found pneumonia to an excessive degree in a warm country such as Panama. This was aggravated by overcrowding and a susceptible population.

Diphtheria shows a wide seasonal range. An outbreak may occur at any time of the year, but is much more likely to happen in the early winter than at any other time. Diphtheria is a disease of cities and of colder latitudes. It is rare in the tropics and subtropics, even in large cities. In other words, the prevalence of diphtheria depends upon two factors, climate and concentration of population. The death-rate in northern states and cities is generally higher than in the southern. Scarlet fever is more variable in its occurrence than diphtheria. High points may be reached at any time from the autumn to the spring: the disease is rare in summer. Measles shows wide seasonal variation. The peak of the curve usually occurs in the cold weather, but may be reached in the summer months of June, July or August.

One of the most interesting facts concerning seasonal influence on disease is the agreement to be noted in cities widely separated and of diverse climates. Much more could be learned by comparisons of this sort.

Hence, neither the condensed, crowded, gel state of humanity in the winter, nor the sol state of dispersion in the summer is an adequate explanation of the seasonal prevalence of the respiratory group of diseases.

A Discussion of the Causes of Seasonal Prevalence

The causes of seasonal variation in the prevalence of disease are varied and complex and not well understood, but they are enticing

fields for study. Some of the probable causes, such as the direct effects of weather and climate, the features of crowding and the problems of susceptibility and immunity, have already been touched upon. These and others lend themselves to discussion.

There may be a lowered resistance, which expresses itself as an increased susceptibility at certain seasons of the year. On the other hand, there may be an acquired immunity of part of the population which acts as baffles against the spread of infection. There may be heightened virulence on the part of the parasite, or if not increased virulence, at least heightened activity, so that its powers of penetration, invasion and primary attack are facilitated at certain seasons and handicapped at others.

The susceptibility of the population helps us in part to explain periodicity but throws little light upon seasonal prevalence. Thus, a severe epidemic of smallpox, plague or typhus fever will leave meager susceptible material for another outbreak. Yellow fever in an endemic area is kept alive by non-immune immigration and new births. It is the fresh susceptible material that feeds the flame. The disease will die out in a city with no influx of strangers, the new-born being insufficient to keep the fire burning. On the other hand, the two-year periodicity of measles is accounted for by the susceptible crop of new babies. This explanation, however, does not satisfy Brownlee, who regards the well-known cyclic recurrence of this disease as due to some factor in the life history of the parasite still unknown. It has been observed that measles shows little tendency to spread during the odd year, despite the presence of susceptible material. Susceptible population in itself is not a satisfactory explanation of the recurrence of disease at definite seasons of the year, although it is evident that seasonal prevalence depends upon susceptible material.

The amount of disease in the community depends to a certain extent upon the amount of virus as well as the facilities for its transfer and related influences. The amount and distribution of the active principle is probably one of the prime underlying factors in the generation of some diseases in epidemic proportions. With some crops, the amount of the harvest depends primarily upon the quantity of seed and its distribution. Studies in experimental epidemiology by Webster indicate the importance of this factor in epidemics of mouse typhoid. Other diseases, such as smallpox and measles, probably propagate themselves entirely independent of the amount of the virus. This is not the case, however, with streptococcic sore throat, which is believed by Bloomfield and Felty to correlate with the amount of the virus and facilities for transfer by close and prolonged contact during cold weather. Dudley has dis-

cussed this matter from a clinical standpoint and brought out the principle which he refers to as "the velocity of infection."

Dosage, or the number of bacteria, also is an important element in determining disease as well as the amount and distribution of the causal agent in the community. It takes at least ten virulent tubercle bacilli of a certain strain to infect a guinea pig. It requires many more tubercle bacilli by the mouth than by the lungs to induce tuberculosis. On the other hand, strains of plague and pneumonia may be so virulent that one bacterium is enough to start a fatal infection. Dosage varies with different infections and with the same infection under different circumstances.

Webster[4] reminds us that the equilibrium of an infectious disease in a given community is determined essentially by three factors: (1) microbic distribution, (2) microbic virulence and (3) host susceptibility. To avert or modify an epidemic, one of these factors must become changed. Webster's studies on mouse typhoid plainly indicate that the inherent virulence of each strain of this bacillus remains constant. He therefore regards virulence as a relatively fixed quality. Racial immunity is acquired slowly if at all. Consequently, the control of epidemics of mouse typhoid depends on influencing microbic distribution. Streptococcal infections in man, such as hemolytic sore throat, scarlet fever and erysipelas, are milder and probably less frequent than formerly. It is quite likely that these infections are becoming less prevalent than formerly. It is quite likely that these infections are becoming less prevalent and less severe because of the measures taken among hygienic people to prevent the distribution of large numbers of virulent streptococci broadcast among the people. In other words, the population now is probably much less heavily seeded with virulent streptococci than it was before the days of isolation, disinfection and understanding.

The seeding of communities with a virus is therefore an important element in epidemic and endemic prevalence. Cerebrospinal fever occurs usually in cold and changeable weather. Carriers are common in the wintertime, rare in summer. The carrier state is persistent in cold weather but recedes spontaneously on the coming of warm weather. Camps in warm climates for carriers of meningococci were advocated during the World War.

Common colds increase the number of pneumococci in the mouth. Normally, about 50 per cent. of the healthy population are carriers of pneumococci. This percentage jumps materially in persons who have common colds. Pneumococci, as well as Pfeiffer's

[4] *Am. Jour. of Hyg.*, 4, 34, 1924.

bacillus and other mouth organisms, increase during attacks of influenza, whooping cough and measles. Scarlet fever seems to cause an increase in the number of diphtheria bacilli in the throat, and a somewhat similar symbiosis is found in the epidemiological relation between other infections.

In a well-seeded community in which an equilibrium has been reached between host and parasite, the introduction of susceptible persons will cause an epidemic occurrence not only among the newcomers but also among the old residents. This can be explained by the fact that the new and susceptible are attacked, and this increased number of new cases causes a general increase in the amount and dispersion of the infection. In other words, the equilibrium reached between the host and the parasite in endemic regions can readily be disturbed so that an epidemic outbreak results. The changes in the body due to season may likewise disturb an equilibrium sufficiently to account for the seasonal tendencies of some infections.

What effect carriers may have upon seasonal fluctuations of disease is not at all clear. The carrier state itself shows seasonal variation in several instances. The best example is found in meningococcus carriers, which are comparatively frequent in cold weather and relatively scarce in warm weather. In diphtheria, the carrier state has been studied both as to season and as to virulence. The number of virulent carriers is directly proportionate to the number of cases and the seasonal curves of the two therefore largely correspond. It is rare to find a virulent diphtheria bacillus in a normal throat or nose, except in persons who have had direct and recent contact with a case of the disease. Carriers explain the vagaries of endemic cases; they account for water-borne outbreaks of typhoid fever and milk-borne epidemics of scarlet fever. Carriers are the storehouse of infection between epidemics, but they do not explain the seasonal prevalence of disease.

The question of virulence and its relation to season is still an unsolved problem. Some infections, like typhoid fever, have quite constant case fatality rates in all seasons, in all places and in both endemic and epidemic situations. With typhoid fever, then, it is possible to construct a satisfactory curve of incidence from the mortality records. This is not so with most other diseases.

The relation of virulence to disease is fundamental and the solution of the problem will require accurate data before a statement can be made with any assurance of finality. Furthermore, this question must be settled for each disease separately, for each disease is a law unto itself. A number of diseases show marked changes in severity at different times and under different circumstances. I have been through some yellow fever epidemics with a

case fatality rate of 37 per cent., and through others a few years later in which the rate was less than 5 per cent. I have also seen the same great variation with smallpox. Scarlet fever is now much milder on the average than formerly. Records of epidemics of infantile paralysis show a great variation in virulence—from 5 to 30.7 per cent. case fatality rate. Flexner and Amoss have shown that strains of the virus passed through monkeys under laboratory conditions fluctuate in virulence from time to time.

We do not know whether disease is more or less fatal on the up or the down curve of an epidemic. There is evidence to show that as an epidemic dies out, the disease becomes more severe, and this has been explained by the fact that as the disease is on the run, the very susceptible are chiefly attacked. Probably the best studies with complete data on this score are those of the great epidemic of infantile paralysis in New York in 1916. This was the most extensive epidemic of this disease in the history of the world—29,000 cases and 6,000 deaths. The case fatality rate was 27 per cent. throughout the rise, peak and fall of the curve. Dr. W. L. Aycock and Dr. Paul Eaton[5] made a study of 38 different epidemics occurring in various parts of the world between 1894 and 1921, comprising 20,568 cases, in which the maximum case fatality was 30.7 per cent., the minimum 5 per cent. and the average of all 20.8 per cent.

Even in a well-organized community where public health administration has reached a high level of excellence, the reporting of deaths and especially of cases is imperfect and incomplete. There are many sources of error. There are fashions in diagnosis which have their vogue and pass. Furthermore, there is a psychology which influences diagnosis and the reporting of disease. Thus, a newspaper scare will at once cause a jump in the number of reported cases and deaths, especially in the group of ill-defined diseases. This is notably the case with influenza. Often typhoid fever and infantile paralysis rise with the intensity with which attention is directed to these diseases, and fall when they pass out of mind. In a study made by Dr. Aycock and Dr. Eaton in my laboratory,[5] it was found that in infantile paralysis the case fatality rate is much higher in cold weather than during the summer season. This would indicate that the disease is much more severe during its sporadic occurrence in the off season than during its summer prevalence. A deeper study of this phenomenon, however, throws serious doubt upon this inference, for experience indicates that infantile paralysis has about the same case fatality rate the year round. It is probable that during the off season only the occasional severe and fatal cases are recognized and reported, while a larger propor-

[5] *Am. Jour. of Hygiene*, in press.

tion of those of the mild and ordinary type occurring in this season are missed than during the months when the disease is conspicuously in mind.

Generalizations concerning seasonal prevalence are hazardous, for each particular infection has its own vagaries. Each disease must be studied in and out of season. Its prevalence may then be correlated with other factors in order to get a true epidemiological picture.

The parasite has its own problems and struggle for existence. If it becomes too malignant and destroys the host before it can get out, it defeats its own purpose. The adjustment towards an equilibrium is therefore complex and exceedingly intricate.

Many diseases follow the temperature curve so closely that there seems to be a direct causal relation between temperature and seasonal prevalence. When the matter is studied a little more intimately, temperature as a direct cause is not so evident. We have the testimony of Arctic explorers that there is little pneumonia among the natives and among those visiting polar regions. It seems also to be a matter of observation that when Esquimos and Laplanders come to our climate, they are especially liable to the pneumonias, and the fatality among them is great. We have the statement of the Grenfell expedition that influenza when carried to the countries of Greenland caused havoc with a very high mortality among the natives. Other reports coincide with this experience. Epidemics of pneumonia and influenza are not confined to cold or even temperate zones, but are seen quite frequently in the tropics. Pneumonia is one of the chief causes of death among the laborers on the fruit plantations in Central America. According to Vaughan, studies in Michigan show that the lower the temperature, the greater the number of cases of pneumonia in that state. The warm cities in the United States have less pneumonia than cold cities, but the warmest city does not have the lowest rate, nor does the coldest city have the highest rate. Temperature alone, therefore, is not the deciding factor.

Scarlet fever shows a distinct relation to temperature. The disease is usually high in the colder cities and almost absent in Atlanta, Los Angeles and New Orleans; it does not even appear in the annual report of the chief health officer of the Panama Canal Zone. Diphtheria differs materially from scarlet fever in that it is prevalent in warm as well as in cold regions. Measles, while showing a very distinct preference for cold weather, prevails in both cold and warm countries.

According to Huntington, the death-rate increases as the temperature departs in either direction, hot or cold, from the optimum,

which is around 64° F. Furthermore, whatever this death-rate, moisture lowers it. At 64° F., humidity has the least influence. This is indicated for the total death-rate, for deaths from non-communicable diseases and from pneumonia, as worked out by Greenberg for certain eastern cities and by Vaughan for Detroit.

Temperature is only an index of the many complex factors that make up the sum total of season and climate. Heat is depressing, cold is stimulating The ill effects of bad air and the good effects of fresh air are due primarily to the physical condition of the air which influences our heat-regulating apparatus. We manufacture more heat than needed and therefore we must lose heat in order to prevent heat stagnation. The loss of heat depends largely upon temperature, humidity and the motion of the air about us. When, however, we consider seasonal changes, we bring in other factors, such as sunshine, storm and variation.

Seasonal influence can not be ruled out, as Huntington states. In other words, the highest death-rate in the spring may not correlate with dryness, but with the fact that people are more fatigued by the strain of winter and are as a rule less resistant to pulmonary infections One of the causes of seasonal prevalence may be due to the stress of increased heat production and metabolism. The body becomes weakened as the winter season goes on and pneumonia continues to increase until the advent of warm weather in the spring. The peak of the disease is reached at different months during the winter in the northern United States, but in any case, there is always more of the disease in February than in August. In other words, temperature seems to exercise a greater influence so far as pneumonia is concerned than moisture.

Vaughan offers the interesting speculation that it is not so much the cold or cold weather that affects us as our semi-civilized response to this cold. Outdoor cold drives us to live in overheated atmospheres indoors. We spend our winter days in temperatures between 70° and 80° F. Houses are overheated, factories are overheated and offices and stores are overheated. It is this fact which helps explain the apparent contraindications in the effect of weather on pneumonia. Physiologically, cold is stimulating and heat is depressing. Practically, cold weather places a greater strain on the body in metabolism and in waste elimination. The body is more exacting. Working under a heavier schedule, it must not be denied its rest. If given a chance—ample sleep, living in cool rooms—the body responds to the stimulation of winter.

It is said that tuberculosis patients do much better in the cold season. Sick people so care for themselves as to counteract the unfavorable concomitants of cold. By so doing, they are in a position

to reap in full the benefits of cold. Arctic explorers are not prone to pneumonia. Thus, it is the habits of life which cold weather induces, rather than the weather itself, which leads to this disease It is for this reason that we may regard much of the pneumonia as humanly preventable. Studies have shown that it increases as physical vitality decreases. When this fact is fully sensed, Vaughan believes that we will adopt the habit of easing up in February and resting in order to counteract fatigue. A more thorough knowledge of the weather combinations will place us on guard in the future, and when the relation between weather and disease is better understood, we may be able to predict the health outlook and even prepare in advance for eventualities.

It is assumed that the limitations imposed by weather and diet cause many persons to lead unhygienic lives in winter. For some of these, spring brings a welcomed tonic change; others seek it by removing to a different locality Taking a spring tonic may have been an old-fashioned notion, but it was moreover an expression of the influence of winter conditions.

A change of climate brings more than a change of scene, and its effects are often real. A change of climate may bring rest and recreation, and also brings the influence of latitude, diet, temperature, moisture and sunshine; it not only means favorable weather conditions, but also removal from smoke, dust and other noxious influences in the air, water and food of the environment in which the person lives. Even the psychologic influences that come with such changes often account for the benefits. When it is all summed up, we must admit that the favorable effects of a change of climate may be due to causes that are not understood at present.

The value of sunshine has always been appreciated, but we have only understood its importance since the work on heliotherapy in tuberculosis, and more particularly the comparatively recent observations upon the health-giving virtues of the direct rays of the sun in preventing and curing rickets.

It is extraordinary that the utilization of certain foodstuffs depends upon sunshine. The rays of short wave length in sunshine have great power to influence the chemical and physical processes of life. Certain substances in buckwheat, also hematoporphyrin or eosin, are not harmful if the animal is kept in the dark, but exposure to sunshine causes serious and even fatal injury. The photodynamic activity of sunlight must greatly influence our well-being both in and out of season. Esquimo children escape rickets because they eat the livers of fish. The negro child in New York is apt to develop rickets unless given cod liver oil.

It has recently been shown that even the weight of certain organs in the body varies with season and directly with the amount of sunlight. Sunlight, then, is one of the potent influences that make up the sum total of climate and explains the seasonal variation in some diseases

Climatology, from the human standpoint, has not yet reached the dignity of an exact science It still banks on combinations of tradition, unverified beliefs and empiric deductions.

A natural explanation of the winter prevalence of contact infection is the condition of crowding in cold weather and the tendency to dispersion in warm weather. Diseases spread by discharges from the mouth and nose are favored by close personal association. People who live together, eat, sleep, work and play together, furnish multiple opportunities for the transmission of infections of the class in question. During the war we found that messmates would run as high as 60 and even 80 per cent. of carriers of meningococci. Bloomfield studied the seasonal prevalence and epidemiology of septic sore throat among the nurses of the Johns Hopkins Hospital, and found that intimate and prolonged association was a factor in the transmission during the wintertime of sore throat due to a hemolytic streptococcus. Gorgas found crowding to be one of the factors in the excessive prevalence of pneumonia among the miners on the Rand in South Africa. It is unnecessary to multiply instances. The effect of crowding is well known, yet it does not give a satisfactory answer to seasonal prevalence.

The schools have also been implicated in the increased prevalence of certain diseases in the fall and winter Students of the subject, however, are satisfied that the schools have comparatively little effect upon the seasonal curve of cold weather infections. Vaughan states that the seasonal curve of disease implicates the weather more than the school. Lobar pneumonia certainly can not be influenced by school attendance. In spite of the opening of school, the peak of scarlet fever is not reached until January, and a secondary high mark occurs in April. Measles is even more deliberate and fails to reach its maximum until May. Vaughan believes that there is nothing in the behavior of these diseases which involves the school as a breeder of disease and states that it is the weather influence in the long run which controls the form of the curve.

In man, as well as in the lower animals, there are distinct seasonal changes which at first sight seem to have nothing to do with disease. The best known of these is hibernation. There is also a seasonal period for reproductive activity. Many animals show variation in the growth of hair, feathers and antlers at different

seasons of the year. These and other periodic physiological activities may be underlying factors in the seasonal prevalence of some diseases. Seasonal changes in metabolism in the lower animals are well recognized.

Beckmann,[6] in a consideration of the effect of season on disease, attributes the absence of such marked seasonal alterations in man to the fact that with higher development comes a better regulating mechanism against extraneous influences. But even in man there are distinct alterations in metabolic activity at different times of the year. Thus, measurements have shown that in spring the hair grows more rapidly than at other times; body activity as a whole is lessened in winter, so that the usual amount of time spent in sleep is much increased over the summer sleep among people not too artificially regulated by customs and alarm clocks. Presumably, this is related to hibernation in other species. It is said that pulse rate, temperature and respiration are highest in winter, and recently it has been found that the height of the capacity of the blood to bind carbon dioxid is reached with the shortest days of the year. In the spring there is a distinct fall in the carbon dioxid tension of the blood, which implies a decrease in the alkali reserve.[7] Although these variations are exceedingly small, they gain in the possibility of significance through the fact that they appear at the time of year when most diseases of seasonal variability are making themselves manifest, excluding diseases dependent on such obvious seasonal matters as insect transmission and food supply.

Man's heat-regulating apparatus is better than that of many of the lower animals. Nevertheless, it is responsive to external temperatures. Thus, a stay for three hours at 40.4° C., with a relative humidity of 95 per cent., will cause a rise of several degrees in the temperature of the body. Likewise, a lowering of body temperature soon results when either the whole or part of the body is exposed to cold air or immersed in cold water. The classic experiments of Pasteur with chickens which are rendered susceptible to anthrax if their feet are kept in cold water is pertinent in this connection.

An illuminating instance of the effect of climate upon physiological activity is found in the laborious observations made by the pioneer American physiologist, William Beaumont, on the gastric conditions in his classic patient, Alexis St. Martin. He recorded with great care the meteorological details and from one group of experiments concluded that "the variations of the atmosphere produce effects on the temperature of the stomach, a dry atmosphere increasing and a humid one diminishing it."

[6] *Deutsch. med. Wchnschr.*, 1922, 48, 1409.
[7] *J. A. M. A.*, 1923, 80, 476.

Seasonal prevalence is also associated with endocrine imbalance. Hibernation is known to depend upon the activity of certain ductless glands. The way this may affect disease directly and indirectly is evident. Moro found that the incidence of infantile tetany increases in January and February, rises to a peak in March and falls nearly to zero in the summer. The galvanic irritability follows a similar curve and in guinea pigs a seasonal variation has been found in respect to their sensitiveness to caffein. Even mental instability has a seasonal tide, for the curve of suicide shows a definite peak in the spring Other mental disturbances follow a similar curve, with a second rise in the autumn in some types.

Hyperchlorhydria is said to show a distinct rise in the spring and autumn, which may possibly be correlated with the diet. Hyperthyroidism seems to show a double curve. Rusznyak[8] believes that the change from winter to summer or from summer to winter arouses an adaptive mechanism, the activity of which produces a condition of instability during these transition periods, and hence pathologic conditions become more conspicuous until seasonal adjustment is completed.

A very interesting contribution to this subject by Brown, Pearce and Van Allen[9] has just appeared. They studied seasonal changes in organ weights and their relation to meteorological conditions. It is well known that many of the endocrine glands of normal animals undergo rhythmic changes in weight per unit of body weight, which conform in general with seasonal conditions. The authors named found that in the case of organs such as the heart, the kidneys and the liver, the transition from one condition to another occurred relatively slowly, and the maximum variation in any direction was distinctly less than that noted in the case of a number of the endocrine glands and the lymphoid tissues. The heart and kidneys showed a variation in weight amounting to approximately 20 per cent., while that of the liver reached upwards of 40 per cent.

On attempting to correlate this series of seasonal variations in organ weight with meteorological conditions, it was found that the majority of them corresponded in time and direction with prevailing conditions of sunlight. In general, the periods of maximum weights coincided with the high levels of daily sunlight, while the periods of minimum weight coincided with the low levels of daily sunlight. Furthermore, the change in direction and the transition from that condition to the other corresponded with the change in sunlight from winter to summer, or from summer to winter. What

[8] *Wien. Arch. f. inn. Med.*, 1922, 3, 379.

[9] *Proc. Soc. Exp. Biol. & Med.*, 1924, 21, 373.

is more significant, however, is the fact that the actual time and progress of the change followed the curve of the actual hours of sunshine rather than the theoretical curve or the uniform progression of the seasons. This was more noticeable in the case of some organs than of others. In fact, it appeared that the weight curves of some organs conformed more closely to the curve of temperature or to humidity than to the curve of sunshine, and that the degree of correlation in any case was subject to the influence of other factors. In other words, there are actual changes in the size and weight of organs which pursue a rhythmic course in harmony with the progression of the seasons.

The study of epizootics under laboratory conditions very closely imitating natural conditions is a new angle of approach and should throw light on the causes of seasonal prevalence. Topley in England and Flexner and his associates[10] in this country have studied mouse typhoid produced experimentally in laboratory animals. Experimental epidemiology with different types of infection carried out over long periods of time and under controlled conditions offers opportunity to unravel some of the mysteries of epidemic disease and its seasonal prevalence

Hunt was the first to show the influence of diet as well as of season in the susceptibility to certain poisons. He demonstrated that mice are much more susceptible to a poison (acetonitril) in the spring following the winter diet than at other seasons of the year. The familiar spring outbreaks of pellagra follow the limited and one-sided diet of the winter. The eruptions of pellagra on the exposed surface of the body resemble sunburn and may be activated by the rays of short wave length. The seasonal prevalence of rickets in the spring is explained by the long-continued absence of sunshine during the wintertime. Scurvy is naturally influenced by season, depending upon the vitamin-bearing food, which is accessory. Stall-fed cattle in the wintertime secrete a milk containing little or no antiscorbutic vitamin, whereas milk from pasture-fed cows contains this important property The seasonal character of certain cutaneous disorders is explainable on the basis of sunlight, while in others dietary variations are probably responsible. In some instances, as in teakwood poisoning, the lesions do not appear until after the activating effect of sunlight.

We see, therefore, that the seasonal prevalence of disease may have a number of different explanations. In some cases it is dominated by temperature, in others by combinations of temperature, humidity, air movements and other factors that make up the sum

[10] *Proc. Nat. Acad. Sc.*, 1921, 7, 319; *Jour. Exp. Med.*, 1922, 36. 9.

total of weather and climate. In some instances it is due to diet, in others to changes in susceptibility and resistance, as a result of seasonal factors. Virulence probably plays a rôle. Sunshine is an important factor in a group of maladies. Again, there is the normal seasonal fluctuation in the physiological mechanism of plants and animals, which is probably a response to the seasonal changes in our environment.

The comparison of epidemics with forest fires is a useful analogy and gives rise to such expressions as "the epidemic burned itself out," or "the epidemic smouldered," etc. These are figurative expressions and do not explain the course of the communicable infections; in fact, epidemics are living things.

The epidemic diseases are phenomena obeying the laws of life and we would expect them to have seasonal fluctuations, just as we commonly observe the influence of season in the plant kingdom. We know that temperature, moisture and sunshine are dominating factors in determining the appearance of blossoms and the activity of corn and thistles, and while each plant seasonally returns with great regularity, the amount of the crop correlates very definitely with a multiplicity of factors, such as the number of seed, the food in the ground, moisture, temperature, sunshine, etc. The amount of the crop, however, is not always determined by the coincident factors of weather, but may be a summation effect, the results of two, three, four and even five preceding seasons which will determine whether we are to have a good crop or a great epidemic.

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THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON

SCIENCE SERVICE, WASHINGTON

ADDRESS OF THE PRESIDENT OF THE UNITED STATES[1]

THE national government has a special and a profound interest in the gathering of the country's scientific leaders which you are beginning to-day in the capital city. No other single agency has so extensively relied upon the men and women of science as has the government. The personnel of the government service and the figures of the annual appropriation alike testify to this. The government has been foremost in employing, and most liberal in endowing science.

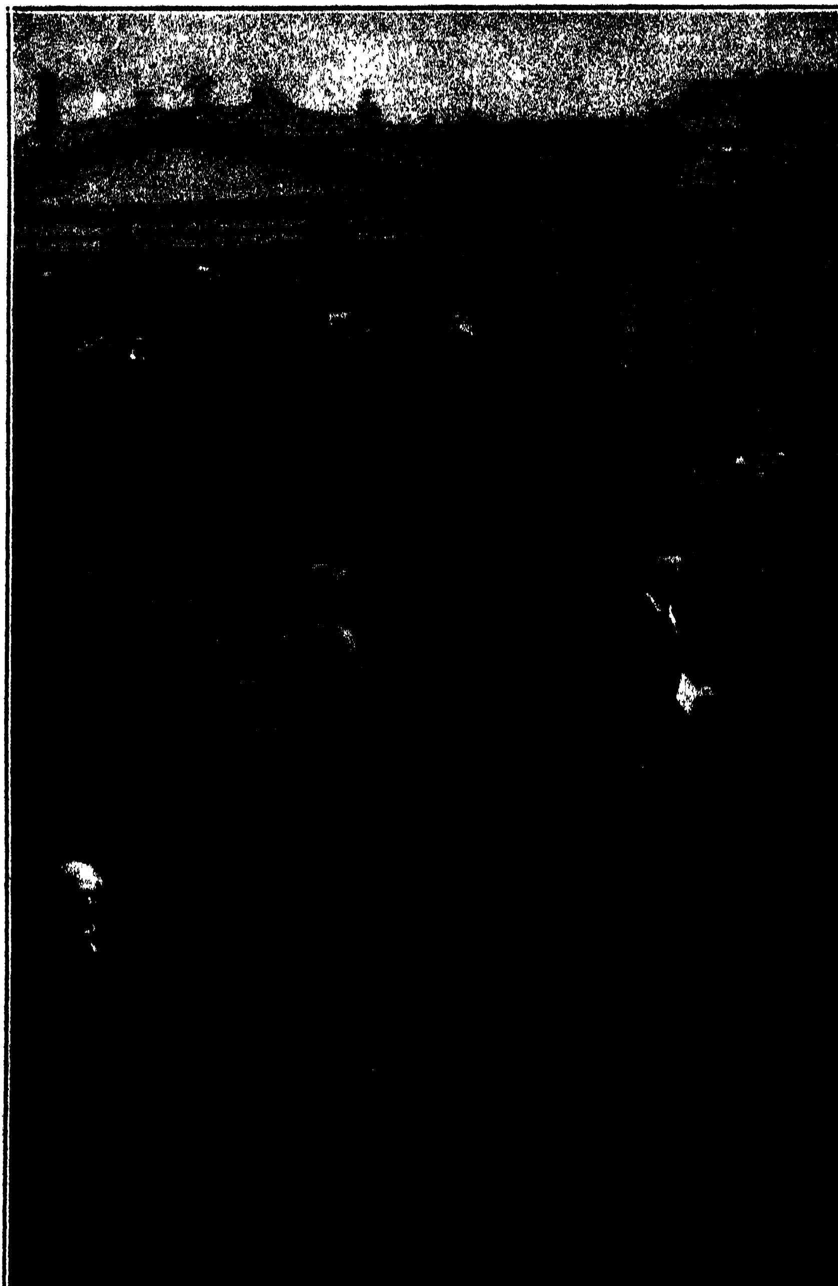
Let me say at once, however, that I do not intend to imply that we have been impressively liberal in dealing with the individual scientists who conduct these activities of the government. The most casual inspection of the salary lists of scientific workers in Washington will make very plain that it is toward science, not the scientist, that the country has been officially generous.

I was impressed with a new realization of the extent and importance of the scientific activities which center here in Washington by some figures showing the geographical distribution of members of your association. In proportion to its population there are more than five times as many of your members here as there are in any state.

I wish time would permit a brief suggestion of the amazing variety, the wide ramifications and the enormous value to the whole people of these scientific activities which are conducted under the administrative departments. Whether in studying the stars or in mapping the bottom of the sea, whether in making two blades of grass grow where one formerly grew; whether in developing a chemical compound that will destroy life or one that will save it; whether in weighing an atom or analyzing the composition of the most distant star—whatever the problem of human concern or social advancement, the scientific establishment of the government has enlisted the men and the means to consider it and ultimately to solve it.

So, as one particularly interested in this governmental university of practical and applied science, I welcome your great gathering to Washington. You represent the interests, the forces and the endless activities which literally from day to day are conquering new domains and adding them to the imperial realm of human knowledge. The future of civilization is well nigh in your hands. You are the wonder workers of all the ages. The marvels of discovery and progress have become commonplaces, simply because their number has paralyzed the capacity of the mind for wonderment. Those of us who represent social organization and political institutions look upon you with a feeling that includes much of awe and something of fear, as we ask ourselves to what revolution you will next require us to adapt our scheme of human relations.

[1] Given at the White House to members of the American Association for the Advancement of Science and affiliated societies meeting in Washington.



PRESIDENT COOLIDGE

Addressing members of the American Association for the Advancement of Science at the White House on December 31. The Washington meeting was larger than any previous meeting and probably the largest assemblage of scientific men that has been brought together in any country.

But we know that you are animated by a profound purpose to better the estate of men. We are confident that society will somehow devise institutions capable of adaptation to the changed circumstances with which you are surrounding the business of living in our world. We trust ourselves to you perhaps with some doubt as to what you may finally do with us and to us, but at least with firm convictions that your activities will save life from becoming very monotonous. And, besides, we realize that if we did not give you our confidence you would go ahead without it.

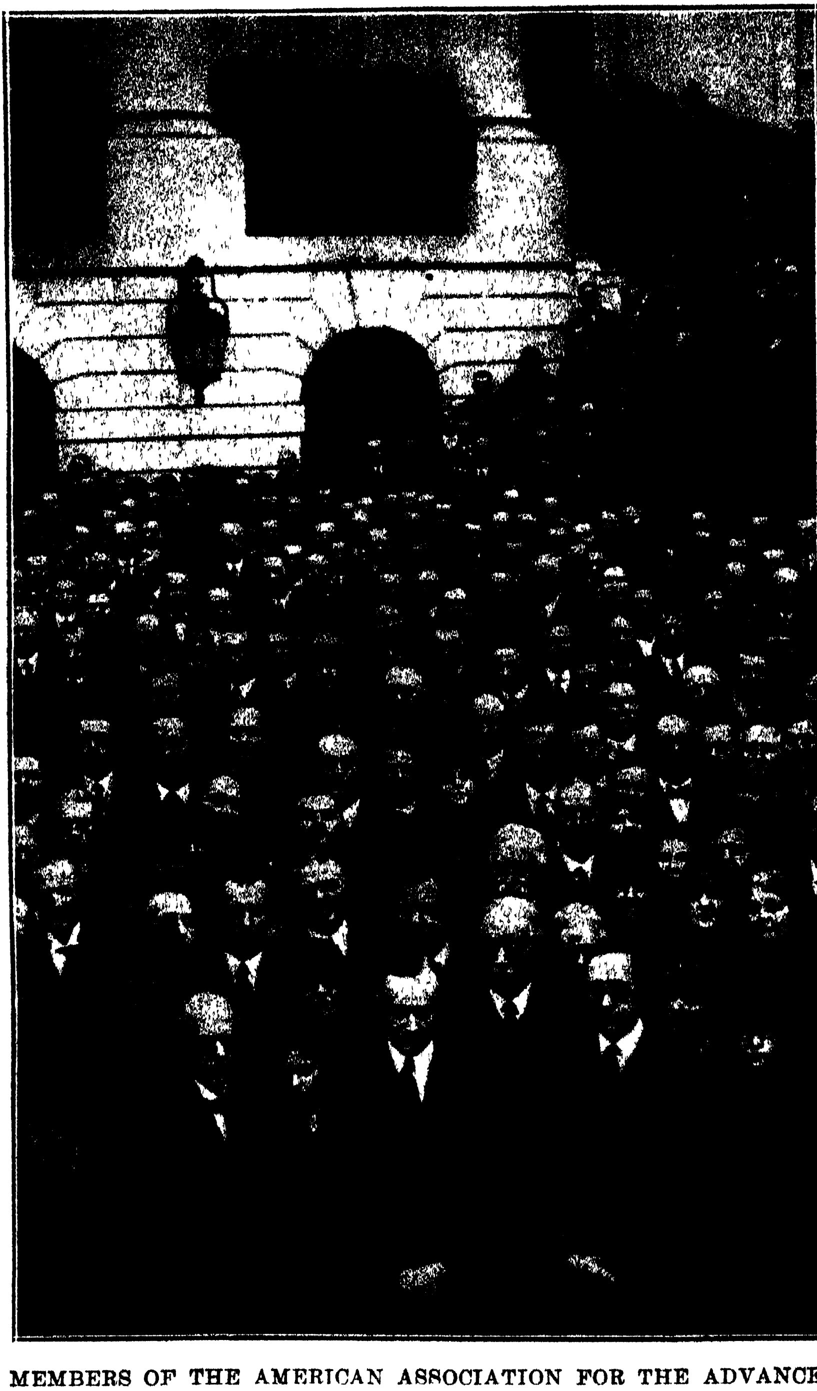
It is a wonderful thing to live in a time when the search for truth is the foremost interest of the race. It has taken endless ages to create in men the courage that will accept the truth simply because it is the truth. Ours is a generation of pioneers in this new faith. Not many of us are endowed with the kind of mental equipment that can employ the scientific method in seeking for the truth. But we have advanced so far that we do not fear the results of that process. We ask no recantations from honesty and candor. We know that we need truth; and we turn to you men of science and of faith, eager to give you all encouragement in your quest for it.

SOME ASPECTS OF INTERNATIONAL COOPERATION[1]

We should think in terms of the cooperation of peoples and not simply of governments. Science knows no political boundaries; she recruits her conquering chieftains from all climes and races. It may be an Austrian monk, revealing the secrets of plant inheritance; or a New Hampshire farmer's boy who learns to fashion instruments of the utmost delicacy and precision; or a Serbian herdsman taking youthful lessons in communication by listening through the ground; or a Japanese devotee of medical research isolating and cultivating microorganisms. In this field all are coworkers and pride is not of race or of tradition, but of achievement in the interest of humanity.

You have properly and insistently urged that international cooperation in scientific research is not only desirable, but absolutely necessary. There are most important enterprises which, if undertaken at all, must be conducted by international collaboration. Take, for example, the world-wide study of earthquakes and of various astronomical phenomena. In history, archeology, zoology, botany, geology and in any other of what are called the natural history or historical sciences little progress can be made in the study of what is fundamental unless there is opportunity to examine all the parts and aspects of the earth. Thus it is manifest, as has well been said, that considered as a local science geology gave only fragments of the earth's history, these partial records being separated in such a way as to suggest intervening periods of cataclysm or destruction. This was the natural interpretation of early investigators, but to-day with a knowledge of a large part of the earth's surface these gaps have been filled and a continuous history is available. It is not possible to have a complete history of life if you have an interrupted geological record, and yet this history is the world's most important story and the foundation of philosophy. You can not have an adequate history of peoples, or even of governments,

[1] From the address of The Honorable Charles E. Hughes, Secretary of State, at the opening meeting of the American Association for the Advancement of Science at the Memorial Continental Hall, Washington, on the evening of Monday, December 29, 1924.



MEMBERS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AT THE WHITE HOUSE

After a reception given by President Coolidge. On his right is Dr. J. McKeen Cattell, president of the association, on his left Dr. William Mather Lewis, president of the George Washington University and chairman of the Local Committee for the Washington meeting.

if you rely exclusively upon data which are obtained in any one nation. And when we come to the enlargement of our knowledge of the universe, whatever may be the value of the discoveries and interpretations made in any one observatory, it is obvious that there can be little progress unless there are stations widely scattered over the earth and the bits of knowledge thus acquired are pieced together.

In truth, scientific achievement is not individualistic, but is the work of groups either consciously formed or produced by the essential correlation of effort. This essential cooperation has recently been described to me in this picturesque manner. "It grows like a building. One man may lay the capstone and get the credit, say an American scientist, but the stone may be laid upon a brick put into place by a Japanese and another by a German, and all may be held in place by the generalization of a Frenchman or a Scandinavian. A scientific problem is like a crossword puzzle worked out in a family circle. The solution may be held up until someone, perhaps accidentally, supplies the keyword that interlocks the rest." It may be added that in science we have a puzzle that is never solved; rather, a succession of puzzles, each answer raising new questions for which there must be a fresh collaboration.

It must be recognized that effective international cooperation depends quite as much on national organization and on appropriate interchanges as upon the creation of distinctive international bodies. There are national obligations which must be met and which can be made adequately only by the aid of governments.

The place of scientific research in our governmental economy should have more appropriate recognition. We develop bureaus, but with all our indebtedness to investigation we are still lacking in proper appreciation of scientific work. It is not comforting to our pride to think of the eminent scientists who are serving our government without adequate recompense or the losses in personnel we sustain by lack of appropriate provision for those who would be our greatest benefactors. If the test of civilization is in the sense of values there is little room as yet for boasting. The most competent organization of national scientific work which will seek, hold and suitably reward investigators of the highest rank is the fundamental requirement.

Then there is the responsibility which each nation should assume of properly assembling, arranging and safeguarding all data and records within the limits of its territory. Each nation should consider itself a trustee in the interest of humanity of all the results of researches in matters either touching itself directly or related to general questions dealing with wider regions. This safeguarding of data and records should be supplemented by coordination of effort and an assembling of results which will make it possible readily to command whatever may be found in any department as to any subject. The tendency is strong among departments to treat themselves as little separate governments, but, whatever distribution of endeavor may be necessary for convenience or economy, government in its relation to its guardianship of scientific data should recognize its undivided responsibility.

Each nation should also acknowledge its obligation in the interest of necessary international cooperation to make readily available to other nations its assembled data and records. The mutual understanding and support of all peoples relating to any subject of research will give ultimately to each investigation and to each separate locality the largest pos-

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EXPLORERS IN WASHINGTON FOR THE MEETING OF THE ASSOCIATION OF AMERICAN GEOGRAPHERS

In the group are, back row (left to right): Willis T. Lee, explorer of America's caverns, at Carlsbad, New Mexico; Frederick Wulsin, just back from a study of non-Chinese tribes of Kweichow, China, where he found fair-haired, blue-eyed Chinese, and Neil M. Judd, who spoke of his recent work at Chaco Canyon, where apartment dwellers are said to have held a tenant's strike 1500 years before Columbus discovered America. In the front row (left to right): Captain Robert A. Bartlett, Peary's companion on his dash to the North Pole; Dr Gilbert Grosvenor, President of the National Geographic Society; Dr. Robert F. Griggs, leader of the expedition to the "Valley of Ten Thousand Smokes," in Alaska, and N. H. Darton, who just returned from exploring the ruins at Cuicuilco, New Mexico.

sible measure of result. This sense of mutual interest and obligation will be of especial importance in opening opportunities throughout the world for archeological inquiries. We deprecate all suggestions of the monopolizing of such researches or their results to the prejudice of reasonable requests to prosecute investigations on fair terms. We trust that our scholars and the representatives of our museums and scientific institutions will receive a cordial welcome wherever they go throughout the world, in the realization that they are not serving selfish interests but seeking to advance the knowledge of mankind. . . .

We should make acknowledgement to you for the benefit of the by-products of your labors. If to an increasing degree we have the security of sound public opinion, if the extravagances and diatribes of political appeals fail of their object, and if, notwithstanding the apparent confusion and welter of our life, we are able to find a steadiness of purpose and a quiet dominating intelligence, it is largely because of the multitude of our people who have been trained to a considerable extent in scientific method, who look for facts, who have cultivated the habit of inquiry and in a thousand callings face the tests of definite investigations. With scientific applications on every hand, the American people are daily winning their escape from the danger of being fooled There are, it is true, many false prophets who are active in those areas of exertion where patient inquiry and regard for facts are not prized, but their following, while strident, is apparently not increasing.

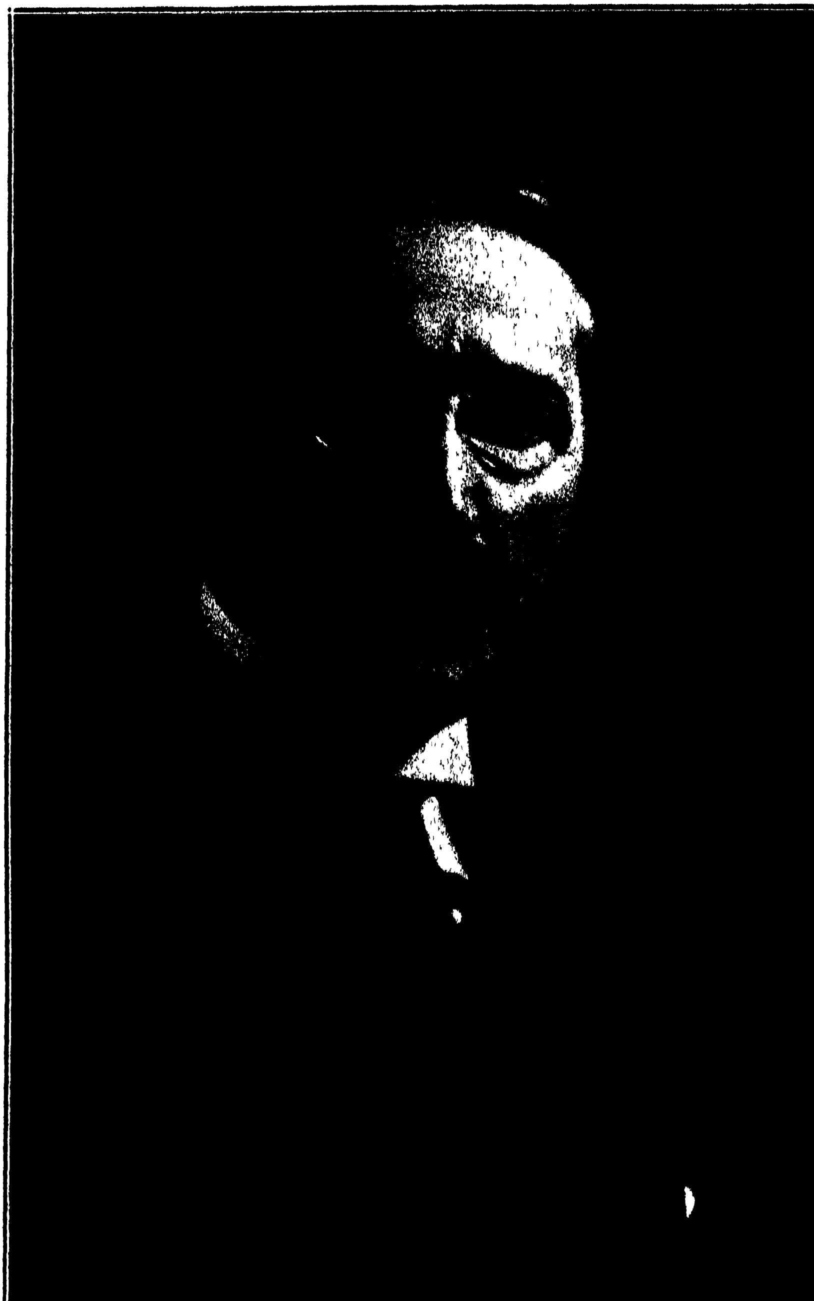
We need your method in government; we need it in law-making and in law-administering. We need your interest in knowledge for its own sake; the self-sacrificing ardor of your leaders; your ceaseless search for truth; your distrust of phrases and catchwords; your rejection of every plausible counterfeit; your willingness to discard every disproved theory however honored by tradition, while you jealously conserve every gain of the past against madcap assault; your quiet temper, and, above all, your faith in humanity and your zeal to promote the social welfare. We need your horizon; your outlook on the world. We need the international cooperation which makes more effective the essential national endeavor and brings us nearer together as members of one human family, who in the presence of science can not remain estranged, but must find means of reconciling their several interests in the harmony of their common aspirations and for the common good.

SCIENCE AND SERVICE[1]

A LARGE percentage of our good agricultural soils have been appropriated, and the further expansion of crop production to feed our growing population must come largely through utilization of the poorer land or through more intensive cultivation and fertilization of existing farms. Even more is this true of our pasture and range lands, the *per capita* area of which has been reduced by almost one half since 1890.

Using almost as much timber as all the rest of the world combined, the United States passed the highest point of *per capita* consumption nearly 20 years ago. Even now four times as much is consumed as is grown each year, and only one fifth of the forest land is set apart definitely for timber

[1] From the address of Dr. Charles D. Walcott, the retiring president of the American Association for the Advancement of Science, Washington, D. C., December 29, 1924.



DR. MICHAEL IDVORSKY PUPIN

Professor of Electromechanics in Columbia University; President of the American Association for the Advancement of Science.

production. In spite of the growing shortage of timber and the mounting costs of bringing it from remote regions, scores of millions of acres of once productive forest land are lying idle, and we are still wasting two thirds of all the wood that is cut.

The story of our wild life and our waters is little different. Birds, fish, shell-fish, fur bearers, game animals, all have reached an alarming stage of depletion as a result of destructive exploitation. Streams, lakes and coastal waters have been polluted. Many of the streams and lakes which could afford a perpetual source of food, power, irrigation water, recreation, water for drinking, sanitation and other domestic uses, as well as channels for cheap transportation, have been reduced in flow or filled with sediment, following forest destruction or unwise cultivation or pasturing on their watersheds.

All these are renewable resources With wise use none of them need have been depleted, and most of them can be made even more productive than they have been in the past. Few would go so far as to contend that such replenishment is unnecessary or undesirable. Many, however, consider it impossible, and even assert that major reductions of the waste in utilizing existing resources are impracticable. The reasons are said to be economic: more intensive farming will not pay, reforestation is too slow and costly, there are no profits in utilizing waste materials.

Yet economic impracticability is frequently only a longer name for ignorance. The discovery of new principles or new methods may make it economically practicable to intensify farming. Better understanding of silvicultural principles and closer study of the life history of our forests will show us how to utilize that resource without jeopardizing its continued productivity, and without increasing the economic burden on the users. Thorough technical knowledge of the product, whether farm crops, timber or what not, will enable us to utilize profitably a great deal that is now wasted.

Our mineral resources, as a general proposition, can not be renewed through human effort, at least in the present state of knowledge. But even with them, the available supplies can be extended almost indefinitely through the discovery of new methods of extraction, or through the discovery and utilization of substitute materials.

To obtain the results desired it is evident that the great masses of humanity have yet to be educated in the scientific method of thought and action, not only in darkest Africa, but here in the United States and in all countries. This is the greatest task immediately before us. All scientific men and women may do their bit—*first,* by training themselves to observe accurately, to think straight and then to record clearly and honestly, and to draw warranted conclusions based on the facts presented, "free from previous preconception and prejudice"; *second,* by reviewing the mass of technical information with which they are familiar and telling the story they have learned in simple, clear language, free from obscure, complicated, technical and verbose wording. These simple suggestions apply not only to research workers in science, but to all the professional classes as well, theologians, doctors, lawyers, statesmen—especially lawyers and politicians, and of course professional teachers in schools and colleges.

That the scientist should have the virtues of charity, tolerance, broadmindedness, patience, persistence and a very high regard for his fellow man is absolutely essential if he is to reach the heights and be of the greatest service. Agassiz and Pasteur were great scientists and great souls, and gave service by teaching as well as by their example of living on a high plane of thought and action. Some other men have been brilliant

contributors to knowledge, although their general manner of living may have been an injury rather than a service to mankind. We need to be grateful for the constructive service of each life, and our criticism of those who have passed and of those who are still active needs to have a broad friendliness as its basis. I believe, too, that a good scientist should be a good Christian, and a good Christian should be a good scientist in his method and work, as both are seeking the truth and the fundamental principles underlying their respective fields of endeavor.

Besides the necessity for each individual to train and conquer himself and to exercise such influence as may be possible on those within his immediate environment, there is great need for him to engage in cooperative public work, by associating with others of similar aspirations, and bringing legitimate influence to bear on all agencies that are concerned in any way with the educational system of the people, from the kindergarten to the university, from the leaflet of the advertising promoter to the great newspapers, magazines and books that make up the thousand and one publications of our day. His influence must also be brought to bear upon the important visual agencies of the motion-picture screen and every other form of illustration, as well as on all those agencies that are seeking to develop "the consciences, the ideals and the aspirations of mankind." The scientific method must be applied to all these factors if we have faith in its ideals.

Is it not practicable for the association to organize a progressive, live committee of men and women to deal with the popularizing of scientific knowledge? It might arrange special sessions for the public to which the layman could go with the feeling that they were for his entertainment and his instruction and not solely to arouse the interest of specialists in their particular field of research. Of all human beings, the child is the greatest and most active investigator of all that pertains to his environment. Why not provide for a junior section of the American Association, and last and in some respects the most important, a woman's section and sessions, at which all the scientific problems of peculiar interest to woman could be considered? We have a strong nucleus of women members, but they should be one of the great influences within the association for developing and carrying forward its work. Then there is the much discussed business man, who has a more or less hazy conception of science and scientific method, depending on whether he considers it affects his interest for good or evil. He would be a better business man, a better citizen and more successful in all his relations in life if he had a working knowledge of scientific method and principles at his command.

Every member of our association should work individually and collectively according to his or her opportunity and ability in supporting the scientific method and in insisting that, in all education of every kind and degree and for all classes, the purpose is to develop without prejudice or preconception of any kind a knowledge of the facts, the laws and the processes of nature in all natural and human relations. The natural weakness and incompleteness of all things of human origin will frequently baffle, mislead and confuse, and may even apparently bring temporary defeat, but in the long run there is no other way to eradicate sciosophy, advance the physical, mental and moral welfare of the race and justify our existence and opportunities for service as sentient human beings.

The Pilgrim fathers knew little of science, but they brought the great principles of law, truth, freedom and faith in God to America. Are we doing all in our power to perpetuate and develop them in connection with the multiplex activities of the world of to-day?

THE SCIENTIFIC MONTHLY

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NEW PROBLEMS OF WESTERN CIVILIZATION[1]

THE CONSERVATION PROBLEM OF THE PAPER AND PULP INDUSTRY

By Professor HENRY S. GRAVES

YALE FOREST SCHOOL

THE extension of the use of paper and pulp products has been one of the extraordinary developments of recent years There is no single material that plays a more important part in our national life or touches the interests of the individual more closely than paper. The ability to secure paper for books, periodicals and newspapers in large quantities and at reasonable prices has been an important factor in education and in the wide diffusion of information to the general public. Each year over eighty-five hundred new books are published in the United States; the daily and weekly newspapers have a circulation of over forty million; while the circulation of the periodical literature of the country reaches amazing figures. Whatever may be said about the quality of some of the material that is circulated in printed form, the immense volume of literature placed at the disposal of the people must count large in the process of general public education.

It requires only a moment's thought to realize the part played by paper in modern business, not only in the vast correspondence and in essential records, but also in advertising. We are told that a billion and a quarter dollars are expended each year in advertising. Probably not less than 70 to 80 per cent. of this is carried through the medium of paper Our minds revert naturally to the use of paper for printing, for correspondence, advertising and the like, and

[1] Papers presented before the Section of Social and Economic Sciences of the American Association for the Advancement of Science at the Washington meeting, December, 1924.

the amount of paper for these purposes is enormous, over 3,500,000 tons a year. Yet this is less than half of our total consumption of paper products. More and more paper materials are entering into commerce in a great variety of forms. One of the large uses, that is increasing at a rapid rate, is for paper board, which includes card and paste boards, strong building board and material for fiber boxes and cartons. The total amount of this material used each year exceeds 2,454,000 tons. Then we require annually 1,059,000 tons of wrapping paper; 356,000 tons of fine-grade paper for writing, ledgers and other special purposes; and an additional amount of 1,015,000 tons of paper and pulp products for miscellaneous uses, including blotting, hanging, carbon, copying, tissue, crepe, wax, onion skin, cigarettes, parchment, cartridge, stencil, tar and building papers, artificial silk, insulating material, felts, imitation cork, leatherette, stoppers, etc. Our total requirements each year for paper and pulp products now exceed eight million tons.

The chief factor in this extraordinary development has been the discovery of methods of utilizing wood fiber in the manufacture of paper. In former days paper was made of linen and cotton rags, hemp, esparto grass, straw and a number of other vegetable fibers. The processes of making pulp from wood were introduced soon after the Civil War, but the total amount of paper made from wood was small, as is shown by the fact that in 1870 only about 2,000 cords of wood were used for that purpose. About two decades passed before the use of wood pulp assumed any considerable proportions. During the nineties and subsequently, the industry grew at an extraordinary rate, and the demand for paper products has now so far outstripped the producing industry that we have to import paper and pulp in large quantities from other countries.

The paper and pulp industry to-day ranks high not only because of its magnitude but also because of its importance in producing materials essential in our industrial and domestic life. There are over 725 paper and pulp establishments in the country with a capital exceeding $900,000,000 and employing about 125,000 persons. It is an intensively developed industry requiring a high degree of skill in the technical processes. The manufacture of pulp and paper requires a large amount of power, the industry as a whole using to-day nearly two million horse power, of which about a half is water power.

The paper and pulp industry is a forest industry, for to-day most of the paper and pulp products are derived from wood. The Forest Service estimates that the paper products consumed in one year by the United States required for their manufacture over nine million cords of wood, while we used only 845,000 tons of rags, straw, Manila stock and other non-forest material.

The expansion of the industry was possible only because we have had readily available large quantities of timber of suitable species and quality. Water power we have also had and an abundance of coal for supplemental power. Great mills have been established at favorable power sites at no great distance from the forest supplies. The whole structure of paper-making and paper use now so essential in our national life has been built up about the forest and depends for its continuance upon the forest. The failure to recognize this simple fact years ago has created a situation that may have grave consequences to a portion of the industry. For the most part there has been in the past no consideration of any possible limit to the supplies of timber. Manufacturers did not provide themselves with adequate timber resources and some relied wholly on the wood market. Meanwhile no effort was made to perpetuate the forests, which were exposed to the sweep of destructive fires and were abused in cutting. And we have to-day the picture of an industry overdeveloped from the standpoint of raw material, and with many mills that are permanent in character facing a constant danger of shortage of pulp wood or pulp. Such a condition is economically unsound and it is already causing serious anxiety to the more thoughtful members of the industry.

I do not wish to burden this paper with a discussion of the processes of manufacture of pulp from wood. We should bear in mind, however, that there are four chief methods of reducing wood to pulp. One of these is mechanical and consists of placing wood billets against great revolving stones and literally grinding off the fibers. A large part of the pulp that goes into newsprint paper is made by this process. The other methods are chemical and differ in the chemicals used for breaking down the wood structure and in the details of the appliances and processes in the factory. The so-called sulphite process utilizes bisulphite of lime, the soda process sodium hydroxide, and the sulphate process sulphide and sodium hydroxide. The bulk of the wood pulp is manufactured by the mechanical and sulphite processes. They are adapted to the reduction of such woods as spruce, the true firs and hemlock, whose wood is soft, light, long fibered and easily bleached. The great mills which manufacture newsprint are equipped with appliances for both processes. Newsprint paper is made up of mechanical and sulphite pulp in the ratio of four to one. The former gives body to the paper and the sulphite furnishes the long fibered material for strength. Many of these mills manufacture also, by the sulphite process, a variety of other paper products. The soda process is used chiefly for making book and fine papers, utilizing such woods

as poplar, tulip-tree, bass wood and the gums, while the sulphate process, a comparatively recent development, is used in producing strong wrapping papers and material for board, and is adapted to the hard pines, larches, etc.

The fact of prime significance in the present discussion is that seventy-eight per cent. of all the wood pulp produced in the country is derived from a limited group of trees, namely, the spruces, the true firs and hemlock. It is natural that the manufacturing industry should have been built up in the vicinity of the forests which contained an abundance of these species and which were reasonably near the chief centers of population. The industry has been largely centralized in northern New England and New York, where the best eastern forests of spruce and fir occur, and to a lesser extent near the spruce and hemlock forests of the Lake States. Still smaller bodies of this type of forest occur in the southern Appalachians where also paper plants have been established. At the present time 41 per cent. of the paper and 54 per cent. of the pulp produced in this country comes from New England and New York, and 22 per cent. of the paper and 25 per cent. of the pulp comes from the Lake States.

The adjacent forests are quite inadequate to furnish the wood necessary to supply the great mill capacity in these regions. The forests have been drained down under a destructive system of lumbering that has given little or no consideration to forest replacement. The virgin forests have been mined and at many points are already greatly depleted of the material suited to large quantity operations.

The present situation in New York is especially interesting. It stands first of all states in the production of paper. Over half of the raw material used in the mills now has to be imported from outside the state—chiefly from Canada. Two thirds of the mills own no timber lands and are therefore dependent on the general market for wood and pulp, little of which can be obtained within the state. In 1920 the spruce consumed at the pulp mills of New York, 59 per cent. of which was imported, cost $2.83 per cord more than in other states. A large part of the industry is therefore dependent upon external supplies that are becoming increasingly uncertain as to quantities available and costs. The situation is likely to grow progressively worse, for the private forests are being cut far more rapidly than they are growing, even though some companies are now endeavoring to practice a measure of forestry. There is a considerable body of excellent pulp wood material in the state forests. At present, however, no cutting is allowed on the public properties. Ultimately some measure of relief to the industry will be afforded

through state timber, but the amount made available each year will be carefully regulated and it can not be counted upon to meet more than a part of the needs of the mills.

The state of Maine is somewhat better off, partly because of the extent of the forests and partly because of the conservative and far-sighted policy of the owners. There is a much better balance between the producing industry and the available raw material. Nevertheless Maine is overcutting its forests and already is importing considerable quantities of wood and pulp from Canada. Moreover, Maine has suffered a serious loss through the depredations of the spruce bud worm, which is estimated to have killed no less than 27½ million cords of pulp wood, much of which can not be salvaged. New Hampshire and Vermont are not as well off as Maine, but are in a better situation than New York. In both cases the continuance of their present production depends upon whether in the long run they can rely upon importations from Canada.

The principal material used by the mills of New England and New York is spruce and fir. In the Lake States these species are becoming so rapidly depleted that other species must be the mainstay of the mills using mechanical and sulphite pulp, except so far as they can import raw material from Canada. The situation may be epitomized by the statement that in 1920 some of the Wisconsin mills were transporting wood a distance of 750 miles from Minnesota and 1,000 miles from Canada. The spruce and fir supplies of the Lake States already have been so far dissipated that the home-grown material will render little service to the industry during the long period of regrowth of the forests. Increasingly these mills will probably adapt themselves to hemlock and to jack pine which are suited to the sulphite process of pulp-making. In any case it is an unhealthy industrial situation that is the result of our improvidence in wasting our forest resources and leaving great plants representing enormous investments stranded without home supplies of raw materials.

The same story could be told of other regions in the East where paper and pulp undertakings have been built up about a center of soft-wood timber supply. The serious part of the situation is that the industrial plants are permanent in character. A self-sustained plant, that is, one manufacturing both paper and pulp and equipped to produce both mechanical and chemical pulp, represents a very large investment. A mill having a capacity of 100 tons per day would require a capital investment of about five million dollars, not including forest lands and equipment for lumbering. The problem is not comparable to that of lumber manufacture. Most lumber mills are amortized within a reasonable period and when the sus-

taining bodies of timber are exhausted the operation is transferred to new territory or the business successfully liquidated. The migratory character of the lumber industry is well known and all are familiar with the progressive movement of the centers of production from the east to the Lake States, then to the south and now to the Pacific slope. Because of the rapidly receding supplies of timber we are paying a constantly increased price for lumber and its products. The situation is tersely expressed in the annual freight bill of 250 million dollars that is paid by the public for transporting lumber long distances. The public is vitally interested in having a large production of paper, available at a reasonable price, near the centers of consumption. The local public is deeply concerned in sustaining the industries that are the chief support of permanent communities. From every standpoint, therefore, an eastern paper and pulp industry is of vital importance.

The foregoing discussion is related primarily to the problem of that portion of the paper and pulp industry that under its present organization is dependent upon the spruce-fir-hemlock type of forests, and which is largely centered in the northeastern United States and the Lake States. The problem of the portion of the industry manufacturing paper from the hardwoods by the soda process and the so-called kraft from the heavier softwoods is far less serious. And the mills in the far west have a supply of material suited to the latter process far greater than their present needs.

The immediately urgent problem, that of the production of paper that depends on the mechanical and sulphite process, is being met temporarily by importations from abroad. We import to-day paper, pulp and wood. We export a certain amount of paper and pulp, but it is small compared to our imports. We actually consume over eight million tons of paper. We produce seven million, leaving a balance of a million tons of imported finished product. Only 60 per cent. of the pulp used by our mills is a home product, the balance coming from abroad in the form of pulp or pulp-wood. If we consider the entire amount of paper consumed by the nation, the American forests contributed only 49 per cent. of the raw material.

That is the present situation. Any consideration of a national policy with reference to providing the country with paper products must take into account future as well as present needs. That the requirements will increase is inevitable. An analysis of the situation has recently been made by the United States Forest Service in cooperation with the paper and pulp industry. Necessarily a prediction of this sort is speculative in character. It is confidently believed that we may look forward to a normal increase of the use

of paper that by 1950 will amount to fully thirteen and a half million tons annually. This would require the use of from fifteen to sixteen million cords of wood.

In looking to a solution of this problem we should consider three sources of supply: First, the continuance of foreign material, particularly from Canada; second, the forests of the Pacific slope and Alaska, and, third, the new growth of forests that may be produced in the East by the practice of forestry.

We can undoubtedly count on a certain amount of material from Canada and other countries. In the long run, however, there are elements of uncertainty in regard to the amounts that can be secured. At the present time we are receiving a considerable quantity of pulp and of paper from western Europe, chiefly Norway, Sweden, Finland and Germany. Whether they can continue to export this material in large quantities is questionable. At present their per capita use of paper is far below that in this country. With returning prosperity it is likely to increase and largely to absorb the products of their paper and pulp mills. It is the present policy of Canada to discourage the exportation of pulp-wood, but to build up pulp and paper mills at home. The eastern provinces have placed an embargo upon the exportation of wood from the crown lands and there has been a widespread sentiment in favor of applying the same principle to wood from private lands as well. How far the growth of population and of the industrial use of paper will divert to Canada the pulp that now comes to this country is difficult to predict.

In this connection we should consider whether we should not as a nation be self-sustaining in the production of paper products. It may be argued that the importation of pulp and wood reduces the drain on our forests. On the other hand, there are cogent reasons why we should not be dependent on other nations for paper, at least that used by the press. The materials needed for educational work and for the diffusion of information should be in our own control and there should be an American industry competent to produce these without danger of serious interruption.

During the last five years a number of paper plants have been established near the great forests of the far west. A preliminary study has been made of the available timber suited to sulphite and mechanical pulp. This survey reveals the fact that there are very large quantities of raw material of excellent quality. Moreover, there is an abundance of undeveloped water power within and near these forests. It is estimated that in the three west coast states there are about 400 million cords of pulp wood of species adapted to the mechanical and sulphite processes of manufacture and as

much more suited to making sulphate pulp. About half of the material available for sulphite and mechanical pulp is the western hemlock. Several varieties of spruce and true fir compose the balance. Hemlock and spruce occur in Washington and Oregon and the firs in all three states. While some of this material occurs in separate bodies most of it is mingled with Douglas fir and other species It happens that the hemlock and the firs have not been prized for lumber on the coast, though the hemlock is more appreciated to-day than a few years ago. The use of the less valuable grades of spruce, hemlock and fir is possible without competing with the lumber industry. On the other hand, they could be logged with the Douglas fir to great advantage. A study in the Douglas fir belt of Washington in 1920 by the government showed that 500,000 cords a year of low-grade material suited to pulp but difficult to sell as lumber could have been taken out in a year in connection with the lumber operations, and in addition about 135,000 cords of timber of good grade but too small for lumber. The timber on the Pacific Coast grows with greater rapidity than in the northeast. Under proper management it would be feasible to support on a permanent basis from the West Coast forests an industry using three and a half million cords of wood of the spruce-fir-hemlock type.

Southeastern Alaska presents a peculiarly favorable field for new developments in paper and pulp production. The forest is wholly coniferous and is composed chiefly of spruce and hemlock. The timber is accessible, the trees of a size to be easily handled, the stumpage prices low and the cost of logging very moderate. There is also an abundance of cheaply developed water power. The largest bodies of timber are in the Tongass National Forest, where the total stand is estimated at about 70 billion board feet. While the timber is serviceable for lumber, the greatest opportunity for industrial use lies in pulp and paper manufacture. The Alaskan forests could provide under forestry methods a permanent supply of at least two million cords per year.

In the Rocky Mountain states there are also bodies of timber suited to pulp manufacture. A great deal of it is adapted primarily to the making of sulphate pulp, but in the northern section, notably in northern and central Idaho and northwestern Montana, there are favorable opportunities for sulphite and mechanical pulp plants. Here one finds spruces, firs and hemlock in abundance and excellent water power. There are in the Rocky Mountains forests probably 80 to 90 million cords of wood suited to the manufacture of newsprint paper. While some of it is scattered and at present inaccessible, large quantities are readily accessible and are available for immediate development.

We have, therefore, in our western forests a supply of pulp wood which from the standpoint of quantity and quality is adequate for our national needs. It has the disadvantage of great distance from the principal centers of consumption and, as already explained, our eastern industry can not be transplanted. The western forests represent a great reserve for future expansion and through the development of the next few years may fill the gap created by the reductions in production that will most certainly take place in the east, due to forest depletion.

We come now to the third source of supply and that is the production of pulp-wood by growth. The permanence and stability of the pulp and paper industry can be assured only by handling the forests under a system of continuous growth of timber. Mining of the forests is bringing us to the end of our eastern supplies. We have not been growing timber in sufficient quantity to take the place of the old trees. Immense areas that have been cut over are only scantily stocked with pulp wood species. A large portion of the areas that are reproducing themselves carry only young trees, so that there will be a long period before they are ready for cutting.

Fortunately the pulp and paper industry is now alive to this problem and steps are being taken by a good many owners to handle their properties with a view to forest replacement. The northeastern forests are now pretty well protected from fire. A certain amount of planting of lands previously devastated is now being undertaken under the stimulus of the cooperative efforts of the state forestry organizations. The methods of cutting still fall short of furnishing the best results in natural reproduction. An examination of the cut-over soft wood lands in the northeast shows a very encouraging amount of new growth coming in. Conditions to-day already warrant, however, a more intensive forestry management of the pulp-wood forests.

Fortunately there is a greater incentive for the practice of forestry for pulp wood than for lumber, because much smaller trees can be utilized for pulp and a shorter period is required to grow merchantable trees. Generally speaking, pulp wood grows at the rate of six to eight tenths of a cord per acre a year. This can be largely enhanced by good forest management. As a rule the growth on the spruce-fir-hemlock lands of the northeast is only about one third of what it might be under intensive forestry. By the application of measures of forestry now quite practicable the growth can be brought to a point that will ultimately give a basis for supplying the full needs of the country for pulp wood. It is believed that the potential annual growth on the spruce-fir-lands of the Middle Atlantic, New England and Lake States will exceed

six million cords. The possible growth in the western forests of this general type is probably over six million cords. In other words, we have sufficient forest land to furnish our needs for sulphite and mechanical pulp if the forests are handled properly.

It has doubtless occurred to you to suggest that the present situation could be relieved by reducing some of the waste that occurs in this industry, as in many others. The greatest loss is through destructive agencies in the forest, *i.e.*, fire, insects and disease. The industry itself is now taking active measures to prevent the deterioration and waste of pulp through fungous disease. It is probable that a larger amount of waste paper could be reused than at present, though already 29 per cent. of all paper produced is reused. Ultimately it may be possible to articulate the paper and lumber industries more closely and to utilize a portion of the sawmill waste. Whether it is feasible or desirable to reduce the use of paper is open to question. Many persons believe that far too much paper is used for advertising, and the average reader would be greatly pleased if the size of newspapers and of many periodicals could be reduced. Generally speaking, this problem is similar to that of the use of lumber or other raw materials. As long as the material can be obtained without serious loss to the country and as long as the use is of service to our convenience and industrial progress, we should seek to provide it.

The possible sources of supply to meet our requirements for paper production enumerated in the foregoing pages will all of them contribute to solve the problem of the paper and pulp industry. The great bodies of timber still standing in the west and the possibilities of producing new crops of timber by growth on lands that will not naturally be used for other than forest purposes place our country in a favorable and independent position for the future.

It would appear inevitable that a considerable readjustment within the industry will take place within a few years. The high costs of bringing wood and pulp from long distances will doubtless cause a reduction in production of sulphite and mechanical pulp in some regions like New York and Pennsylvania, where the remaining timber supply is so much restricted in contrast to the manufacturing capacity.

It is hoped that foreign supplies will continue in quantity and at a cost to make these adjustments gradual, pending the establishment of a proper economic balance as between mill capacity and local supplies of raw material. In any case the question of the practice of forestry is such an important element in the problem that immediate steps should be taken by the industry to bring the forest lands into the best possible condition for tree growth and the

public should cooperate with the industry in a most liberal spirit.

The statistics in this article are largely from the Department Bulletin No. 1241, U. S. Department of Agriculture, 1924.

POPULATION PROBLEMS OF SOUTH AMERICA

By WILLIAM A. REID

General Observations

It has been said that of the billion and a half and more people who dwell upon this earth of ours a larger number are evincing migratory instincts than at any former period. Every one knows that the abnormal conditions of the nations during the past decade have increased the desire to wander. This spirit is reflected in countries of sparse population as well as in the most densely settled nations of the world. Australia, with fewer people per square mile than any of the continents, finds some of her citizens developing wandering tendencies. A number from the Antipodes actually emigrated and colonized in Paraguay in the heart of South America. As a reversal of the movement, a group of fifty discouraged Argentine families removed to Australia to start life, as they believed, under more propitious circumstances. Canada, with millions fewer people than the dominion needs, is forced to part with numbers of her best workers, who sail for South America. The United States, more willingly, of course, witnesses scores of western planters and stockmen moving to lands of the southern continent. Overpopulated Italy gladly contributes to help people the newer regions of the earth; and the former Perene colony in eastern Peru illustrates the attempt to place Italians in large numbers on the borders of semi-civilization. Japan encourages her citizens to emigrate, and from that country a rather steady flow of natives is moving to South America in general and to Brazil in particular.

Railways of all the continents are moving a vast number of passengers, many of whom belong to emigrant classes. It is not unusual to find transcontinental trains in the United States well filled, often crowded; trans-Canadian, trans-Siberian, trans-Australian and trans-Andean railway services are experiencing active passenger traffic. Suez and Panama report that the movement of peoples in increasing. Eastward through Suez thousands of Europeans, especially Britons, are migrating from congested areas to the sparsely settled Australia and New Zealand, while Panama witnesses Europeans passing westward to South or Central America.

Indeed travel, migration, human movement—call it what you will —is active everywhere.

When I think of this great movement—this restlessness of peoples of all climes—I am reminded of a scene, miniature in comparison, that once came before me. It was that of herds of cattle, camels, sheep and goats wandering aimlessly over parched regions of the earth in northern India Thirst and hunger had curbed the spirit of animosity that usually prevails when animals of different classes are thrown together, and, suffering and bellowing, they tramped onward—somewhere—anywhere—more docile, less bellicose.

So as people of all races migrate here, there, yonder, about the world, serious minds are asking questions. Will this meeting and commingling of human beings, as they find new homes and possibly more promising futures, bring tranquility? Will it in time render people more docile—less militant? Will composite populations be endowed with greater tolerance and will the western world with its abundant spaces be the haven of hope and work and peace?

Let us look at a few population problems of the vast South American continent—a continent not yet peopled, and, indeed, a new world toward which thousands are turning with wistful eyes. In doing so we must remember that South America is a continent—not a country. One might really be justified in attempting a discussion of the population problems of a country, but could the justification be extended to such a gigantic task as that of the population of a continent? The answer calls for a book, not a brief paper. On the other hand, every one knows that South America—a cluster of independent nations—has certain things in common. All the republics are underpopulated; all of them attained independence about the same time; all are storehouses of diversified raw materials; all extend the hand of welcome to the proper kind of immigrant; all the conquering peoples speak a Latin tongue, and all the republics are obtaining much of that vitalizing influence—capital—from other continents.

Overpopulated and Underpopulated Areas

In South America the same instincts of the North American are to be observed in respect to urban and rural populations. Natives of the several countries as well as immigrants have the tendency to congest in larger cities. In a government investigation of this condition conducted in Buenos Aires it was found that in certain districts there were from three to twenty families living in one house and as many as nine persons sleeping in the same room. Again, the province of Buenos Aires is the home of nearly half the people of the republic. In the five larger cities more than two million people have their homes.

During the past 50 years there have settled in Argentina more than 2,000,000 Italians, about 1,200,000 Spaniards, more than 200,000 French, 50,000 English, 70,000 Hungarians, 50,000 Germans, 30,000 Swiss, 22,000 Belgians and smaller numbers of other nationalities. The latter include several thousand from North America. Of the 178,000 emigrants who left Italy last year, about half of the number went to Argentina

In the 12 years ending in 1919, Italy sent 166,000 settlers to Brazil. The Italian population of Brazil, including children born of Italian parents, is estimated at considerably more than 2,000,000. In the state of Sao Paulo more than 1,000,000 out of a population of 3,000,000 are Italians. More than one half of the inhabitants of the city of Sao Paulo are of Italian blood.

Overcrowding in Chile is reflected in recent investigations by the Federal Labor Bureau. It was shown that 37,967 persons were living in 712 tenement houses. The average number of persons per room in Valparaiso was 3; Antofagasta 2.69; La Serena 3.33; Concepcion 2.42. The report further shows that of the 23 provinces of Chile, Valparaiso, the smallest, is the most densely populated, having 200 persons per square mile. The province of Santiago comes second, with 100 persons per square mile.

Chile has not received immigrants on a large scale. For ten years prior to 1914 the arrivals are shown to have been not more than 2,500 per year; and since the World War the European has not come to Chile in numbers. In traveling about the country one often hears the slogan, "Chile for the Chileans," which seems to indicate that the national spirit considers too many immigrants more detrimental than profitable. Still there is room in Chile for millions more than she possesses if they come gradually and are assimilated. But they can not colonize in the north—in the desert—and the several German colonization schemes that were tried in the extreme south were not a success.

From immigration statistics issued by the Oficina Internacional del Trabajo it appears that immigrants arriving in Chile at present are coming in larger proportion from countries of northern Europe than is true of other South American countries. France and Germany are credited with 19 per cent. each, and Spain and England sent 17 per cent. each of arrivals. Of the remainder, Italy supplied 13 per cent., the Netherlands 7 per cent., Belgium 4 per cent. and others 4 per cent.

Uruguay, with a population of 1,603,000, increased its people during 1923 by about 38,000. There was an excess of births over deaths of 22,000, while immigration amounted to 16,000. These figures are official estimates, as Uruguay has not taken an actual census enumeration for some years.

Bolivian population, still under 3,000,000, is huddled together on a parallelogram half a hundred miles wide and 400 miles long. The great majority, of Indian origin, are mine workers, primitive agriculturists, tenders of herds of sheep, goats, alpacas, vacunas and llamas. The people cling to highlands and leave the lowlands, stretching for hundreds of miles from Cochabamba, Sucre, the Yungas Valley to the Paraguay River, to the few human beings who spend their lives where nature is prodigal and progress little known. One of the Bolivian problems, therefore, is to settle the vast eastern plains; and at least two activities foreshadow the inflow of new peoples—the Bolivian government's railroad building scheme and the development of petroleum in the Santa Cruz region by a great American corporation.

Germans have settled in every South American country. In Brazil, Argentina, Chile, Bolivia and elsewhere they own large plantations, banking interests, commission houses, etc. In southern Brazil it is estimated that there are more than 200,000 Germans.

"What are your population problems?" I asked an Ecuador official in Guayaquil. "Problems—problems," said he, "we have no problems. Oh, yes, it is difficult for our producers to market their crops. If we had more railroads and highways—if we had modern communication from Quito and Riobamba into our eastern plains, you would see more ships in Guayaquil and more immigrants seeking homes in Ecuador." Later, I chanced to hear expressions of another prominent Ecuadorean; he said: ". . . We lack population. We need capital, workers, railroads and highways, machines and modern tools, to undertake farming and mining on a large scale. We need engineers, geologists, men of action and enterprise to import capital and labor, without which the people of Ecuador will indeed remain relatively behind in the race."

I inquired of a Colombian diplomat as to the outlook for the settler in his country.

"Our problem is largely one of improving transportation, of connecting Colombia's numerous railroads. Some work of this nature is now in progress, and highways are being given further attention. We have established airplane service, and the trip from the Caribbean coast to Bogota consumes only eight hours instead of eight days or longer as in the past. As transportation facilities gradually extend we can place judiciously a larger number of immigrants. Colombia's population of 6,300,000 is only 13 persons per square mile and is small compared to our area of productive lands."

THE AGRARIAN QUESTION

Sustenance for the human family, of course, comes from the earth, and South American countries are regions in which man has

made little more than a good beginning in modernized or intensified tilling of the soil, working the mine, tapping the forest; although stock-raising and wool production have passed the experimental stage. But the word "intensive" can not be applied to agricultural and industrial South America in a similar sense to its significance when we speak of Belgium, Holland or Japan.

First of all problems after government is land. There is land, productive land everywhere for the rich man, but unfortunately and truly there is little land available for the man without means. That, to a greater or lesser extent, has been the condition since the coming of Europeans. In no country of South America is the outlook for land ownership more than fairly satisfactory for the poor man. For years public-spirited citizens and some legislators have sought to solve the agrarian problem; but they have found that they, themselves, are often the offenders. So vast are hundreds of estates that have descended from family to family for generations that they are mentioned by square leagues rather than by hectares and acres. Argentina furnishes an illustration of this condition. In the Pampa region, 30 per cent. of the land is owned by fewer than 100 persons, whose average holdings are 112,000 acres; in Misiones, one of the rich agricultural provinces, 42 persons, averaging 135,000 acres each, own 97 per cent. of the land; in the far south similar conditions prevail, where more than 50 per cent. of the land is held by 36 individuals.

Argentina, by reason of her greater railway mileage and large immigration, furnishes a suggestion of what might be accomplished were it possible for the immigrant to obtain a small piece of land at reasonable cost and on the long-term payment plan. Land on a connected system of railways or along river courses is not available at what might be termed a reasonable cost. On the other hand, there are abundant cattle and agricultural areas in the distant or inaccessible parts of all the republics. An illustration is that offered by Paraguay, where a few years ago an American corporation acquired a million or more acres of productive land at the insignificant price of 65 cents per acre. The work of building a railroad from the Paraguay River to and through the property was among the first activities undertaken, for without a railroad or highway outlet the interior lands were useless. Now, railroad-building calls for capital. An individual with small means might acquire lands in these outlying districts, but the chances for success would be very small without a modern means of dispatching his products to outside markets.

Some of the leading railway systems of the eastern republics have been instrumental in placing immigrants along their lines by

providing small farms and granting the immigrant a series of years in which to work and pay for the property. The Central Argentine Railroad furnishes an example, where 20,000 foreigners were settled on or near its lines during a recent year. Other railroads are doing the same thing, an activity that promises good results.

Tropical Inertia

The equatorial belt extending around the world casts its spell of inertia for three thousand miles across South America. Thus, vast areas of Brazil, Venezuela, Colombia, Ecuador, Peru, Bolivia, Paraguay and the Guianas—more than half the political divisions of the continent—are included within the hot or warm zone. In parts of these areas man has avoided making a permanent home. To be sure, in these hot lands there are not only settlements but also towns and cities where the native population has been augmented by the coming of people from cooler areas of the several countries as well as from lands over the seas.

Those of us who are familiar with tropical lands of the east and with tropical lands of the west are aware of the prevailing lethargy—there is the same disinclination to manual toil—to any physical exertion But the east with its teeming millions has had for centuries certain advantages over the west. One of these has been the inflow of Europeans who have directed the operation of natives. In other words, the people coming from northern Europe, possessed of energy and progressive ideas, often backed by capital, exerted a stimulating influence on the native population and also caused a limited dissemination of sanitary knowledge. The second advantage, from a business and health point of view, is that the laborer of the east is not burdened with clothing. A loin cloth is all that is worn by the Eastern tropical worker, which gives him the advantage of better health than the tropical laborer of South America, where even the lowest class wears at least the trousers of civilized man. Tropical rains and a burning sun have limited effect on the oil-anointed body of the Oriental worker; while these same elements play no minor part in causing sickness of the South American tropical laborer, because when his clothing becomes wet, it is not changed but dries on the body. The point I would make is that high mortality among tropical workers in South America is a condition that can be improved by sanitation and education. That it is possible to surround laborers and their families in tropical jungles with health safeguards has been demonstrated again and again. Conspicuous examples were the conservation of life of the laboring masses at Panama; of those who finally succeeded in building a railway around the rapids of the Madeira River in Brazil, and the

measures that changed Rio de Janeiro, Santos, Guayaquil and other cities from high mortality to healthful places in which to live.

Brazil, so large and so varied in land, soil and climatic conditions and with only about ten persons per square mile, would at first thought seem to offer unlimited opportunities for the immigrant. But Brazil, like smaller countries, is not prepared to receive immigrants faster than they can be assimilated. There are parts of Brazil where human beings in numbers have been so swallowed or overwhelmed by the forests that few escaped. For instance, a large party of dissatisfied workers on the Mamore-Madeira Railroad, in the early stages of that enterprise, attempted to raft and boat themselves back to civilization. To leave the jungle by a trackless land route would have been even more hazardous than the one adopted. Yet we are told that a small percentage of those who essayed to escape the Mamore region actually reached Para. They died of starvation, fevers and exposure.

The struggle against nature in this instance reflects conditions that prevail to-day in tropical South America. The rich jungle lands are there, but it requires capital and, as a rule, operations on a large scale rather than individual effort to combat primitive nature. Come with me to another interior region of Brazil. Imagine you are on the Alto Parana River at the Falls of Guayra, which stand at the head of steam navigation. Twenty-seven miles of railroad connects the lower and upper waters of this artery of trade. For several hundred miles up and down stream one finds here and there a settlement, with from one to two shacks to a hamlet of eight or ten "habitaciones." While most of the land is owned by absent landlords, natives and a few foreigners are battling to keep from being overgrown by rank tropical growth. These people are maté workers, lumbermen, tobacco growers. "How long have you lived here and why do you stay?" I asked an Italian who operated a diminutive trading post at Pirey, one of the settlements to which I refer. "I have been here three years," he replied. "I am married to a Paraguayan, and we like this country life better than Asuncion. Some day I will go back to Italy, but not until we make money here buying and selling things. It is too quiet here for most people who come from cities. Some immigrants are sent here by the government, but usually they go down the river to Posades or Corrientes. They want to be where there is more life and more business. They are not tropical pioneers."

Inadequate Transportation Facilities

The marketing of products that have been raised, mined or produced has always been a serious problem in South America. The

countries that possess the greatest railway facilities, like Argentina, Brazil, Uruguay and Chile, have, of course, profited by modern traffic facilities, but these have been inadequate. Fluvial navigation, especially in eastern and northern parts of the continent, afforded a means for transporting commodities to the growing settlements on the coast or on rivers that reached the seaports. Engineers, you know, abhor hills and mountains and favor the course of rivers in selecting the routes that railroad constructors are to follow. Capital dictates the general region to be tapped, but the engineer actually selects the route of least resistance—the route of the stream or river. What is the result? Vast and virgin regions have not been tapped by transportation. And the region where there is neither river nor railway service to the exterior the settler has, as a rule, largely avoided. Let me illustrate.

Santa Cruz de la Sierra in Bolivia, situated near the geographic heart of South America, is about 500 miles from a railway on the west and a like distance from the navigable Paraguay on the east. The sparse population raises by primitive methods sugar, rice, fruits and other foods. Those not needed locally are sent toward the four cardinal points by man's most primitive carrier—his own back and on mules and donkeys. It is true that a motor car—the Ford—did actually arrive at this secluded place, but the wretchedness of the trail leading from the Paraguay River so wore its parts that the car never was in form to be driven back to the Paraguay.

Housing and Health

Fewer palatial residences for the rich man and more livable homes for the poor man are conditions that need adjustment in all South American countries. Look at Copacabana, in Rio de Janeiro; Plaza San Martin, in Buenos Aires; Vina del Mar, in Chile; Plaza Colon, in Lima, and a hundred other places. Then turn your attention to the thatched cot and the mud-built hut with the ground floor to be found in populated regions of any part of South America. Look at the people, for instance, who dwell in rural Bolivia, Paraguay, Venezuela or northern Argentina. Many of them, born and bred amid squalor and poverty, know of no higher form of living. Oftentimes, however, the rich landowner or the corporation that profits by the labor of these downtrodden humans could at very trifling expense, comparatively speaking, make laborers more comfortable, conserve their health and thereby insure a steadier flow of workers to a given enterprise.

Among the most conspicuous efforts to house and care for the laborer that it has been my privilege to examine are the new workmen's homes in Buenos Aires, in Santiago, those of the Chile Ex-

ploration Company at Chuchicamata, and the new homes in the region of Santa Marta, Colombia. Among the improvements at the last two places, modern sanitation, health safeguards, hospitals, trained nurses, surgeons and other remedial agencies have resulted in saving thousands of lives.

Those who are unfamiliar with the progress of modern and medical education in the southern continent will be surprised should they read a book entitled "South America from a Surgeon's Point of View," by Dr. Franklin H. Martin. It shows that a few scattered hospitals have grown to many such institutions and medical courses are liberally provided, thus permitting those of modest means to pursue the study of medicine. In former years it was mostly the sons of favored families who could really equip themselves as physicians and surgeons by study in Europe. To-day the South American medical schools, according to Dr. William J. Mayo, are the "equal in equipment and methods of theoretic teaching of any in the world." The progress in sanitation in most of the countries has been marked, and the recent visit of the United States Public Health Service officials to South American countries and the measures of international sanitary cooperation entered into between South American and United States officials foreshadows a gradually lessening mortality.

CONCLUSION

Varied activities for conserving population are to be noted in each South American country, but to enumerate them would be too lengthy for this paper. I refer to only a few illustrative cases: the new land settlement service of Brazil; Uruguay's school for training municipal nurses and efforts to attract young women from the best families; Argentina's national housing commission and its work in saving babies and in providing better homes for laboring classes; Chile's new housing commission which has stimulated life conservation; in Colombia, the lessons taught by foreign capital in caring for laborers and their families, which lessons are being extended by national authorities; the sanitation and modernization of Guayaquil, and at least a change of attitude toward the laborer by at least some of the landed proprietors; the introduction of modern sanitary appliances and underground sewerage in the Bolivian capital; the awakening in Venezuela for modern highways and the actual building of a number of miles of such roads; Peru's new laws in behalf of the laboring classes and explicit stipulations to employers of labor, and in Paraguay the exemption from all taxes for five years on homes constructed by the poorer classes.

Will tropical inertia ever be eradicated? Perhaps not, but when we look at activities and accomplishments in Java, the Straits Set-

tlements, Ceylon, Cuba, Panama and scores of other sun-parched and rain-drenched lands, who can doubt that the hot regions of South America may not one day become as livable, as productive and as profitable? For example, suppose some rubber corporation would devote as much capital to Amazonia as one American company did in Sumatra. Granted workers are available, is there doubt of practical and satisfactory results?

Will isolation disappear? Certainly, but slowly. Look at the factors working on the problem of isolation. There is the radio, the telephone, the highway, the motor car, the village "movie," the railway, the steamboat, the rural mail delivery, as well as other influences that carry life interests to even the most secluded estancia. Select any one of the ten South American countries and we find all the above-mentioned forces being gradually extended.

These factors of inertia and isolation are being further relieved by what some persons aptly term "mechanical civilization." This really means the partial removal of manual labor from hundreds of employments, and the application of electrical, steam and oil energy; it signifies, for instance, the employment of the giant harvester and thresher in place of the hand cradle and the sickle. Labor-saving devices serve equally well in hot lands and in isolated regions. So, in considering some of the problems I have found that "mechanical civilization" has made a good beginning and I confidently expect to see life, conditions and production radically changed and strengthened within comparatively few years.

Crowded Europe, with 476 people per square mile, and more crowded Asia, with about double that number of persons living in similar areas, look to the new lands of the west for homes and fields of labor. South America with only eight persons per square mile has ample space for millions of additional human beings. The several nations bid the newcomer welcome. But this coming of people must be on a reasonable basis. The current should not be too rapid and those who do come must possess a spirit akin to that of the forty-niners who crossed the plains of the United States, banishing the buffalo, stocking the ranch and plowing the furrow. It is just such sturdy pioneers that South American countries need—those inured to toil, and particularly to toil in the open country.

When a former president of a South American nation is engaged as an ordinary clerk; when a son of a South American admiral is working his way through an American college; when the son of a South American millionaire is serving under tropical sun day after day as an irrigation engineer; when a former cabinet official is pleading for a clerkship to keep the wolf from the door, and when these few cases are typical of thousands, we may believe that so-

called aristocracy is passing through evolution, just as are the land barons and social butterflies of Great Britain. And when intellectual workers are joining hands with manual laborers and these two forces marching phalanx-like, guided by reason and not by the rashness of the student, it must be realized that the days of the hidalgo are never to return. I am reminded of an ancient custom in China, where once a year the ruler, in order to dignify labor, put his hands to the plow and turned the furrow; and of Captain John Smith, who ordered that those too proud to work should not eat; of the remarks in our day of Sir Philip Gibbs, who says: "Departed are the privileges of a wealthy and leisured crowd—gone forever is the age-long allegiance to caste, dividing class from class." South Americans, I believe, are appreciating the dignity of labor to a greater degree than ever before, and are realizing that their problems can not be solved without the inflow of new peoples. Wise heads therefore plead for a fair deal for the newcomer, for a piece of land for him to cultivate, a modest but comfortable home; in other words, welfare and contentment—for a contented middle class in the lifeblood of nations.

RACIAL DIFFERENCES IN MENTAL ABILITY

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IN a city containing such a large percentage of foreign-born adults as Cleveland, and in a job dealing entirely with the study of human reactions, one can not work very long without coming up squarely against the problem, "What rôle does nationality play in the mental development of children?" or "Does the development of intelligence depend upon the race from which the individual has come?"

As in any school system, the attempt is here made to keep the progress in the different buildings uniform, so that children can move between buildings without loss of time or inconvenience. This uniformity is often very difficult to obtain; teachers in one building may slave to get the same results that are obtained with ease in another place. The question at once arises, "What is the cause—environment or heredity?" As a partial answer to this question, about four years ago a study was made by Mrs. Abrams, using a group test to study children in the first grades.

It was found that in the schools chosen tests showed the following rank: American, Jewish, Hungarian, Bohemian, Colored, Polish and Italian in order of success in the test. While the different

nationalities coming from the separate schools were grouped together there were variations between the buildings. The Jewish children tested brighter than the average child in some districts and less than the average in others.

The conditions were these: In the latter districts the housing conditions were very undesirable; as a result just as soon as a family could amass enough money to move or showed an interest in better surroundings, they moved out to the better districts. Consequently only the dregs of the Jewish group were left behind in the schools where the children showed such poor results. In these districts, there were a large number of "charity families" and homes with defective children.

When abroad, I had the pleasure of working in a very cosmopolitan laboratory, in which fifteen different nationalities were represented at the time. In that group was a Polish countess, through whom we became acquainted with her fellow-countrymen, who impressed us with their high degree of intelligence and ability. Imagine my surprise to find in Cleveland the general feeling that the Polish people were a dull race, that they did not learn well in our public schools, etc. This fact, coupled with another fact, namely, that the Bohemian group was regarded as having much higher ability, was very intriguing. Here again, the laws of selection may have played a rôle.

Our first Polish groups were brought into Cleveland by the owners of the steel mills. The officers went to Europe and brought over boatloads, often moving whole villages and transporting them bodily to their present locality. In these places they have stayed, laboring hard, putting up with adverse working conditions, clinging to customs and homes, manifesting little disposition to change their conditions. On the other hand, among the Bohemians were a large number of social and political refugees; people who fled from conditions that were undesirable and who are seeking social freedom.

We will now see if the results of the clinic give any clue to this difference in the groups. For the last five years, a careful record has been kept of the nationality of the parents of the children tested by the clinic. The present study is based on the records for the last two years. During that time over 14,000 examinations have been made. As at least a year must elapse before a child is retested there are as many separate children as examinations made. These children were all carefully tested by skilled psychologists. Every attempt was made to eliminate any adverse factors due to timidity or lack of understanding. Failures due to language and personality of the child and of the psychologist were carefully noted. Cases where the results might be challenged were not recorded here. The child's nationality was based on the nationality of the father and

the language spoken at the home. For that reason you will find Jewish used in this study rather than Russian and Polish Jews. There were two types of colored, those coming up from the south and those who have always lived in the north. Since the war and during it, Cleveland had a large influx of southern Negroes. The larger percentage of the colored children examined were from the south.

Boys and girls were grouped together for this study, although there were 25 per cent. more boys than girls. This factor together with that of chronological age affected all groups alike. The children studied ranged in age from four to twenty-one years; the largest group tested was between five and eight years of age. There were very few children below five or above sixteen.

In some of the nationalities, the number of individuals studied were so small that it was felt that chance would make results valueless. As a result no groups are mentioned here except those in which two hundred or more children were examined. These groups are arranged in order of number of children tested: American, Italian, Polish, Negro, Hungarian, German, Jewish, Czecho-Slav, Slavish (Jugo) and Slovenian. (On comparing it with the chart taken from a study made in Cleveland in 1921, it is found that the number tested is not always the group with the largest percentage of children in the Cleveland school.) This study as can be seen is different from the usual study on correlation of nationality and mental ability.

No selection based on nationality was made in picking the children to be examined. The data was taken from those referred to the clinic for other reasons. A child is brought to the clinic because he stands out from the regular group either because of his unusual slowness or very great ability in school. So the present curves suffer from a marked askewness, especially in the relation of the percentage of subnormal to normal children tested. In order that there be a common means of comparison the Terman I. Q. was used and we have the following results.

Grou	Belo 25	25–5	50–6	65–8	80–9	90–1	110–	120–	Over 140	Total
American	0	41	224	639	567	851	351	261	30	2,964
Italian	0	28	287	732	435	379	6	4	0	1,881
Polish	0	40	397	654	331	236	21	2	0	1,681
Negro	0	43	413	583	320	196	9	10	0	1,575
Hungarian	0	19	133	310	224	267	13	9	1	976
German	0	10	125	247	165	207	41	24	3	822
Jewish	0	16	74	145	149	234	100	88	9	815
Bohemian	0	8	58	139	133	125	27	8	0	498
Slavish (Jugo)	0	17	114	168	88	75	7	3	0	472
Slovenian	0	5	67	131	62	73	7	3	0	348

As can be seen from the table the Jewish group, although only one half as many were examined as the Polish group, had over forty times as many children who would be called bright; they had, on the other hand, less than one fourth as many children who were so seriously retarded that regular school work could not be given them.

Since the number of children tested in each racial group are not the same the comparisons below are based on the percentage of children tested and not the number of cases.

(1) All the curves show a certain amount of likeness between the groups—small numbers of cases at each extreme and an askewness due to the fact that few normal children in comparison to those who vary from the average are tested by the clinic.

(2) The percentage of children classed as borderline or below in each group would be as follows (the figures after the names of the group represent the total percentages of those whose I. Q. was below .80): Negroes—65 per cent., Polish—65 per cent., Slavish—63 per cent., Slovenian—58 per cent., Italian—55 per cent., Hungarian—47 per cent., German—46 per cent., Bohemian—41 per cent., American—30 per cent., Jewish—29 per cent.

(3) The groups arranged according to those having a large percentage of bright or unusually bright children (I. Q.'s above 110) examined would be as follows: Jewish—24 per cent., American—22 per cent., German—8 per cent., Bohemian—6 per cent., Slovenian—3 per cent., Hungarian—2 per cent., Slavish—2 per cent., Polish—1 per cent., Negro—1 per cent., Italian—½ per cent.

(4) In spite of the above ranking of children below borderline it was noted in the case of children classed as "Imbecile" the Jewish and American groups had as many as any other one; in fact, more than the Negro and Slovenian groups.

As these studies have been based on local conditions, no sweeping statements can be made. They give, however, a rather interesting glimpse on the laws of selection, both artificial and natural.

THE COMPARISON OF RACES

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THIS paper does not presume to cover with any sort of completeness either its subject or the related subject of intelligence tests in their application to the members of different races or the questions of racial superiority and inferiority which in Japan, in South Africa and in India, as well as in our own country, are so deeply

stirring the minds of men to-day. Nor can I make any pretension to scientific or erudite authority; my only warrant for expressing a judgment in such matters is an experience for the past six years and a half at Hampton Normal and Agricultural Institute, a school for Negroes and Indians at Hampton, Virginia, established in 1868 by General S. C. Armstrong, carried forward after his death by Dr. H. B. Frissell, and most famous, perhaps, as the institute where Dr. Booker T. Washington, of Tuskegee, received his training. My single present purpose is to utter a brief *caveat* against the loose, wild, hasty, clearly unscientific generalizations which have confused the thinking even of intelligent and scholarly persons upon these matters. In few fields of human inquiry, I venture to believe, has there been such unrestrained darkening of counsel by words without *knowledge.*

One might have supposed that the World War would have put an end to the intellectual arrogance not only of Houston Stewart Chamberlain, but also of his disciples and the whole cult of "Nordic" self-laudation. But it continues; and one sees even in such titles as "The Passing of the Great Race" and "The Rising Tide of Color" the not over-subtle suggestion that the progress of the peoples of the earth who do not happen to have pale skins must bring overwhelming disaster and perhaps annihilation to those who do happen to have pale skins. The innate inferiority of the darker races is commonly taken for granted; when statistics are gathered and used, they are sometimes gathered carelessly and used not quite justly; and when the powers of a despised race are under discussion there is often an undue freedom in the assertion of the universal negative, with a surprising neglect of the logical axiom that only a single contrary instance is needed for the refutation of such argument.

To come down to specific facts, a recent and widely discussed case of this sort has been the examination of the "intelligence," so-called, of the drafted men in the Army of the United States during the World War, and the inferences drawn from the resulting figures. The Alpha test, given to the literate soldiers, covered, in the data which were gathered for study, 103,500 white men and 19,000 Negroes. On the basis of these data, it was concluded that the average mental age of the white drafted men was 13.1 years, and the average mental age of the Negroes was 10.4.

But it should be remarked that these tests were commonly given, so far as we know, *by white men* to white and black soldiers, not by black men to either white or black soldiers. When you have a white officer examining a black private there is a variable factor of fear, hesitation and unreported misunderstanding for which some

allowance should be made, and for which, so far as I know, no allowance has ever yet been made. What is called in logic "the universe of discourse" of the black soldier and his white examiner must frequently have been entirely different. The black man might easily fail to grasp what the white man was asking him. A few years ago, when visiting the Indian reservations in South Dakota, I found that Indian boys and girls applying for admission to Hampton Institute were invariably stumped by the question in the application blank, "Have you any *physical defect?*" They could talk English, but not that kind of English: those two words meant nothing to them. One suspects that a similar gap between the language of the white psychologist and the Negro or foreign-born private soldier must have occurred much oftener than was ever revealed.

Furthermore, it has been pointed out by Dr. Horace M. Bond,[1] the median scores of the white recruits from certain southern states were below those of the Negro recruits from certain northern states. His table of comparison follows:

Median Scores

Whites		*Negroes*	
Mississippi	41.25	Pennsylvania	42.00
Kentucky	41.50	New York	45.02
Arkansas	41.55	Illinois	47.35
Georgia	42.12	Ohio	49.50

The simple, natural, obvious conclusion to be drawn from such figures is the one to which Dr. Bagley, of Columbia, and many other experts have come: that the army tests revealed not so much native, inherent intellectual alertness or ability as general knowledge based upon schooling and home backgrounds. Inevitably the Negro soldier whose school experience had covered only three, four or five months in the year would, as a rule, make a poorer showing than the white soldier who had gone to school for more months in the year and probably for more years of his childhood. But there is no material here for dogmatic statements about the comparative *inborn* ability of the two groups.

With this view accords the conclusion of Miss Ada H. Ashitt,[2] after studying several hundred children of different races in a district of New York City. She writes:"No study of racial differences which fails to take into consideration the social status of the group tested can be considered valid." In like fashion, Dr. Thomas R. Garth has written:

[1] *Opportunity*, July, 1924: "What the army tests measured."

[2] "On the need for caution in establishing race norms," *Journal of Applied Psychology*, Vol. V, No. 2. Quoted by Dr. Bond.

The elements in a study of racial mental similarities or differences must be these: (1) Two so-called races, R1 and R2; (2) an equal amount of educational opportunity E, which should include social pressure and racial patterns of thought; and (3) psychological tests D, *within the grasp of both racial groups* [italics mine]. We should have as a result of our experiment R1ED equal to, greater than or less than R2ED. In this experiment the only unknown elements should be R1 and R2. If E could be made equal, the experiment could be worked.[3]

Dr. Garth might well have added, "and if D could be made *equally comprehensible* to R1 and to R2." But of course this can never be surely accomplished, any more than the total educational experience of two individuals of differing race can be made identical. The careful investigator will simply recognize these two variables and make whatever allowance for them seems just.

A similar attitude is shown by Dagne Sunne, of Newcomb College, in a recent study, published in *School and Society*,[4] comparing white and Negro children on the basis of verbal and non-verbal tests. The Myers Mental Measure and the National Intelligence Tests were used. It is remarked by this observer that:

The lower performance level of the Negro pupils must not obscure these facts: Individuals of both racial groups are found among the highest and the lowest three per cent. at every age level; the highest score in National Intelligence tests was reached by a white girl and the highest score in the Myers Mental Measure by a Negro girl and the third highest by a Negro boy; 1.2 per cent. of the white and .3 per cent. of the Negro children attained scores above 80 on the Myers Mental Measure, and 1.6 per cent. of the white children obtained scores higher than the upper limit of the Negro on the National Intelligence test. "This difference in the percentage of the two groups at the upper limit may be significant but it is small."

And, finally:

It is difficult to determine how much racial differences and how much differences in school training and social conditions contribute to the divergence in test results. For an accurate determination of facts, it will be necessary to study the development of the same groups of white and Negro children for consecutive years in physical and mental growth and in school achievement.

In connection with this question of the comparative ability of white and Negro pupils, some statistics which were gathered at Hampton Institute several years ago may be of interest and value. In the Record Office, where the previous history as well as the school and later record of each student is kept, seven degrees of color are distinguished—black, dark brown, brown, light brown, light, very light (ordinarily those who would be known as Negroes only by their hair or other features, not by their color), and with "no trace"

[3] "White, Indian and Negro work curves," *Journal of Applied Psychology*, Vol. 1, No. 1.

[4] Vol. XIX, No. 486, pp. 469–472 (April, 1924).

(indistinguishable from white persons). In the investigation under consideration the classification of students according to color was made by two observers for the sake of securing a higher degree of uniformity.

The number of Negroes entering the institute in all classes for whom complexion was so recorded, from 1901 to 1910, was 2,404 (of whom 1,468 were males, 936 females). The color distribution was as follows:

Color	*Number*	*Percentage*
Black	39	1.6
Dark Brown	873	36.3
Brown	519	21.6
Light Brown	587	24.4
Light	304	12.6
Very light	64	2.7
No trace	18	0.7

The comment was made at the time when these figuers were collected that "the present high percentage of mulattoes is probably due to the fact that the mulattoes have been more favored as regards education, both by the white people and by the colored people." In the older days, the house servants and their children would be apt to have the attention and interest of their masters and mistresses or employers, and in general to be stimulated by the example and influence of white people to learn to read and write and cultivate their minds. It was natural that a good many in this group should be of mixed blood.

The scholastic records for these students, classified by color, show that on the whole there is little difference between the different color-groups. Such variations as are found seem, as has been said, quite as likely to be due to previous schooling as to any other cause. It can not be affirmed that any significant conclusion can be drawn as to the influence of either white or Negro blood upon mentality.

The color-classification of the twenty-one[5] best scholars (salutatorian and valedictorian) of the graduating classes at Hampton for the past eleven years (1914–1924 inclusive) may also be worth noting:

Of the Valedictorians:	*Of the Salutatorians:*	*Of the whole number:*
3 were dark brown	3 were dark brown	6 or 28.5 per cent. + were dark brown
3 were brown	3 were brown	6 or 28.5 per cent. + were brown
3 were light brown	3 were light brown	6 or 28.5 per cent. + were light brown
1 was light	2 were light	3 or 14.2 per cent. + were light

[5] Omitting one Indian.

It is evident again that, so far as color may indicate the degree of white or Negro blood, it signifies little or nothing with respect to intellectual ability. Indeed, as one reflects upon the really *known* evidence, the actual facts, it seems high time to throw overboard the whole notion of the *general* superiority or inferiority of any race. Let it be freely granted that one race will excel in one respect—as the Finnish competitors in the Olympic games this last summer excelled in long distance running—and another race in some other respect. Every man may rightfully believe that his people are the chosen people to lead the world into one province of truth if not into another. The time-honored allotment of government to the Romans, philosophy to the Greeks, religion to the Hebrews, as their respective spheres of preeminence in world-history and their distinctive contributions to the progress of civilization represents an entirely reasonable principle. India has for ages believed passionately in the supremacy of the spiritual life; let us honor her for that and learn all we can from her, instead of looking upon her with coarse contempt because she does not compete with the West in mechanical invention and highly organized industry. The Chinese have always been admired by those who have really known them for their capacity for hard, painstaking work, their peaceableness, their honesty, their fundamental ethical soundness. Why despise them because they have not yet developed a Standard Oil Company or built a modern battleship or learned to regard a national championship in baseball as of more interest than a presidential campaign? So one may gratefully recognize the exemplary courtesy and loyalty of the Japanese, the mystical fervor of the Russians, the thoroughness and the tough-mindedness combined with tender-heartedness of the Germans, the clear if not always practical logicalness of the French, the artistic sensitiveness of the Italians, the sense of color and music and rhythm, the depths of patience and devotion, the indomitable hopefulness and cheerfulness which we find in the African race? Does not the world need them all? Can not we Anglo-Saxons learn from them all? Have not all these characteristic racial virtues a proper place in the vast pattern, the infinite fabric of the past, present and future life of humanity? Is it not worse than foolish, is it not ridiculous and abominable when we find members of the Anglo-Saxon race boastfully proclaiming *their own superiority* to the rest of mankind, chiefly because they happen for the moment to control politically and industrially a large part of the earth's surface? Does it not savor of what the old Greeks called ὕβρις, the shameless arrogance, the wanton insolence, which fears no law of God or man, and sooner or later receives the Divine punishment? We know what we think

of an individual who so thinks of himself more highly than he ought to think. Let us realize that a similar combination of resentment, ridicule and contempt is often excited in the minds of the members of other races by Anglo-Saxon self-complacence and condescension. Before we write books on our own race as "the great race," let us wait to be assured of that title by the scholars of some other race.

In other words, the existence of racial *differences*, points of strength and weakness, talents and lack of talents is and always will be plain and undeniable. Any sensible mother will admit that her children do not all excel in every good quality. One is superior in orderliness, another in literary appreciation, another in dramatic sense, another in the ability to learn foreign language, another in mathematics, another in financial acquisitiveness, another in philanthropy and so on. But will their mother claim all-round superiority for any one? Probably not.

In like manner, when we are comparing the races of the human family, let us confine ourselves to the narrow limits within which measurements and judgments can be surely made. Let us not talk broadly of physical or intellectual or moral excellence: let us divide and specify and differentiate. Only so can we reach justice and truth.

This is a small planet on which we dwell. It will never be any larger. We can not move off it. We must learn somehow to live together upon it in decent neighborliness. More than ever is it plain to-day that among men and women who call themselves civilized there must be no toleration of race-prejudice, but rather mutual respect and a growing good-will.

THE USE OF THE MEDIAN AS A MINIMUM REQUIREMENT FOR INTERNATIONAL MIGRATION

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THE improvement or impairment of the human stock of any country is dependent on the one hand on the relative quality of the immigrants and of the natives, and on the other hand of the infants and adults. Eugenic progress can be accomplished if immigrants are superior or if the children are superior or both. Should the immigrants as a whole and the babies as a whole be inferior, racial decline is in operation.

Eugenicists are, of course, very greatly interested in the differential fecundity of the components of a population, and at the same time greatly discouraged by the subfecundity of the more intelligent, to remedy which eugenicists are making a discouraging uphill struggle.

Let us turn then to see what might be done by the control of accessions by immigration. Here, on the contrary, we find a promising situation in that public opinion is already convinced that immigration should be greatly restricted and that it should be on some selective plan. The present immigration selection is defective because it is based on group characteristics rather than individual characteristics, and in each of these groups a very great range of variation with great overlapping is found. But by an extremely simple and wholly feasible plan we can adopt a procedure that accomplishes the eugenic desideratum—so that immigration can improve the race. This device is merely to exclude all below the median which is the theoretical individual inferior to whom are one half the population and superior to whom are one half the population. Thus no one is admitted who is not an asset. All liabilities are debarred. It is true that for any of the characteristics we might measure there are many individuals close to the median score and that the score would have some probable error so that the line may not be cut without a possible injustice to individuals above or below the median by a very small amount. Yet this is habitually done in civil service examinations and college entrance examinations. This slight injustice is relatively trivial as compared to the injustice of a very superior person found to have arrived just after the fulfillment of a quota, the previous successful person having been a dullard.

We pass now to the criterion of which the measure will be made. The desiderata of such a criterion are first ready and feasible quantification. Conforming to this criterion are physical, mental and educational tests. There is no difficulty in making tests of any one of these types with so wide a range, and so good a reliability that excellent quantification is attainable. I know of no other. Occupation and civil records are too variable and uncertain to permit feasible quantification. As at present, they will be of incidental use. Of the three tests mentioned, we may discard the physical test median because mental and moral values are of so much greater social significance and because physical condition is so variable during the lifetime of the individual. Educational tests offer greater usefulness and may well be employed if mental tests can not yet command sufficient public confidence, but the mere environmental factor is so much greater than in the best constructed

mental tests that the mental test is clearly the proper choice. A further advantage lies in the fact that one mental test has already been given to a large representative group of men and the results of a representative sample of it have been collated. While this was done separately for white and Negro draftees, the results are readily combinable in proportion in population. The resulting array shows, using the "combined" score, a median of *13.25* in a scale having a range of 0–25, the mode is *13–13.9* and the arithmetical mean is *13.30* It is, therefore, seen that it is not a matter of great moment which kind of average is used, but for reasons already given the median is the best threshold. Some criticism may be raised that the scores in this array did not include some who were too inferior to arrive at military camps or on the other hand were exempted because they were already in officers training camps or exempted as indispensable to industry. Since these omissions come from opposite ends the effect is in some degree compensatory. An investigation of the facts would indicate roughly some slight correction of the median cited above, but it is certain to be very slight and while worth making, no great harm would result if the median, as here given, were to be used.

Of course, it is not proposed to use either of the two tests, Alpha or Beta of the combined scale, since psychometry has made great strides since those tests were given. Further the purpose of the new tests would lead to certain differences in their construction. After completion the new tests and the old would be given to several thousand immigrants to get the equivalent of the old median in the new tests. The language difficulty is not insurmountable. The tests would be prepared in about a score of the commoner languages and there would be a pantomime-administered test, using objects instead of paper and pencil for the illiterate.

The administration of the tests should be at about a dozen well-distributed permanent offices of the immigration bureau attached to various legations abroad.

While the new test would replace tests for feeble-mindedness and literacy, since the former is measured by the test and an illiterate above the median should be admitted. It is not proposed to abandon present requirements in reference to physical condition, social record, etc.

The plan is recommended for adoption by all countries. Obviously it is of most advantage to those countries who attract the largest number of applicants for admission. But it is also of international advantage, for it will most improve the stock of those countries whose resources make possible a great growth of population and hence it would be of greatest world benefit. Consider the

analogy of farmers who have the better land on which they can greatly increase the number of cattle. They are especially concerned with admitting only superior stock to their herds. Thus cattle as a whole will be much more improved than if he simply accepted without selection the offerings from other farmers who did not have the land to greatly increase their herds.

In conclusion I plead for a more rational test of immigration restriction, namely, one which would admit individuals superior to our median as obvious assets, and the exclusion of those inferior to our median as being those who would lower the quality of our stock. No temporary profit from needed labor can compensate us for the loss in permanent lowering of American quality by the admission of inferiors.

MODERN BUSINESS EDUCATION AND RESEARCH

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PRECISE definitions should probably come at the end of a discourse rather than at the beginning, but nevertheless it is sometimes necessary to mark out the ground in a preliminary way at the very outset, in order to avoid confusion. This is particularly necessary with the subject of business education and research, since this subject has seen a relatively recent development and has not yet undergone much standardization with respect to terminology.

In the first place a distinction in principle should be made between business training and business education. The former prepares for some particular commercial occupation, such as stenography or bookkeeping, and is not unlike vocational training for a particular trade. Business education, on the other hand, must be regarded as a grounding in the principles and laws that underlie business as a whole, with little reference to a specific commercial occupation, in which respect it is comparable to legal, medical or engineering education, as these have come to be conceived.

The distinction between training and education is important in all these fields, but in the field of business the distinction is not yet fully adhered to in practice. The development here has been so recent that commercial-training and business-educational courses are spoken of in the same breath, when only the one or the other is meant. Thus we have the anomaly of so-called "business colleges" which teach only stenography or bookkeeping and

"schools of commerce" in colleges, which offer cultural business courses pure and simple. Nor does the confusion end here, for a number of collegiate schools of business still offer a hopeless mixture of commercial training and business educational courses. Not only stenography and bookkeeping in secondary schools but many other special training courses of one kind or another are still passing for cultural educational courses in our schools and colleges. In this paper we will be concerned chiefly with business education and not with commercial training, although the two phases will of necessity have to be taken up together in the earlier paragraphs.

A similar need for clear-cut distinctions appears with respect to business research. Two distinct phases are to be observed—the one, research in or for or by business and, the other, research about business. Research in business, for business or by business is conducted for the purpose of immediate gain, such as the sales or marketing research carried on by some particular corporation, or business forecasting services prepared for and sold to business houses, or the broader studies of business problems pertaining to a whole industry which are conducted by an organization of the business men in that industry. Research about business, on the other hand, is not concerned with immediate gain. Its object is to gather basic facts about business as a whole for the purpose of deducing general principles. This type of business research is carried on mainly through our universities and through privately endowed bureaus or agencies, although some of the universities carry on research for business also. A little later we will go into further detail regarding these two forms of business research. Here I simply wish to point out that we will be concerned with both forms in this paper.

Turning to the development of business education and research and to their present extent, we note a phenomenal situation. On the educational side there has come a tremendous and increasing demand in recent years for courses in business, especially in the public high schools and in the colleges, but likewise in other institutions. The high schools of this country have shown unprecedented activity along all lines in the past thirty years, their enrollment showing an increase in that period of some 600 per cent., which is obviously out of all proportion to the increase in population. But with all this unusual total advance, enrollment in business courses in public high schools has increased three times as fast as the sum total, its increase in enrollment being 2,000 per cent. in the past thirty years. A recent survey has shown that at the present time anywhere from 25 per cent. to 70 per cent. of the high-school students in our large cities are enrolled in business courses.

A similar situation confronts us in collegiate business education. Thirty years ago the collegiate school of business was virtually unheard of in this country. To-day there are between 25 and 30 such schools with an enrollment of over 20,000 students. In addition, many colleges having no schools of business offer business courses in their departments of economics. On this basis a government survey for the college year 1921–1922 indicated a total of 103 collegiate institutions offering business courses to over 73,000 students and conferring during the year over 4,000 college degrees in business.

Nor is the picture complete with public high schools and colleges. Y. M. C. A.'s, part-time and continuation schools, corporation schools, trade-union colleges, correspondence schools and other private and governmental agencies have entered the field of so-called business education until all in all this represents one of the outstanding developments of the present generation.

Turning to the side of business research, the development in recent years has in its own way been quite as marked as has that of business education. It is more difficult to measure this in quantitative terms, for no adequate survey of the development in all its ramifications has yet been made, but from the information available, it is quite evident that the business research idea has spread to an astonishing degree in this country in recent years. The three most important centers of business research activity are the government, business itself and the universities.

The business research work of our federal government has become a staggering proposition. We take for granted so many things the government is carrying on to-day that we often lose sight of the fact that some of them are of exceedingly recent development and have expanded with unprecedented rapidity. This is particularly true of governmental business research carried on by the Departments of Commerce, Agriculture, Labor and other departments. It would take us too far afield to attempt any adequate survey of this development, so that one or two illustrations must suffice. We pass over the work of such well-known agencies as the Bureau of Labor Statistics or the Federal Census of Manufacturers. The work of the Bureau of Crop Estimates, operated by the U. S. Department of Agriculture, has been carried on for a number of years; but though widely utilized, the enormous amount of research entailed in this crop-reporting service is not generally recognized. The crop reports, issued monthly during the crop season, cover nearly one hundred different cereals, grasses, fruits, vegetables, live stock and other products raised on our farms and ranches. Data are secured through some 32,000 township reporters, 2,800 county

reporters, and a corps of paid state field agents and crop specialists. These data relate to acreages, conditions, yields, quantities and values, and are sent in on prepared forms to Washington, where a special crop-reporting board prepares the results for publication each month. These monthly estimates are remarkably accurate and furnish a most valuable source of reliable information for the business man.

Another illustration of what the government is doing along the lines of business research is seen in the recent creation, under Secretary Hoover's direction, of the Domestic Commerce Division of the Bureau of Foreign and Domestic Commerce. Its program of work, as indicated by the assistant chief of the division, divides itself into four phases: First, it conducts country-wide surveys and market analyses of commodities and industries; secondly, it prepares in convenient summary form data relating to production, consumption and general business conditions; thirdly, it disseminates this information through bulletins and public addresses; and, fourthly, it acts as an information bureau for the business man and makes special research studies on topics of current interest. This governmental division is building up files of important research data available to all. The way in which this bureau is serving American business men is indicated by the fact that 5,000 inquiries per day are now being received and that its work has doubled in the past two years. During the past year this bureau supplied information on 1,250,000 inquiries from American manufacturers, exporters, financiers and domestic merchants. Limited space prevents the inclusion of other illustrations of the striking way in which the government has expanded its business research activities in recent years.

In addition to the wide use being made of governmental facilities, business men are engaging in extensive researches of their own. Many large corporations have installed special research departments to deal with marketing and other immediate problems; but the most significant development here has come through associations of business men, the bankers, the manufacturers, the farmers, the railroad executives, the meat packers and other groups, who have pooled their interests and have opened up centers of business research activity of considerable proportions. A single instance may be cited where some thirty national associations of manufacturers have combined to form a conference board of manufacturers, which engages a staff of from eighty to one hundred people to carry on business research into problems of interest to all manufacturers. Something like 100 research reports have already been issued by this board bearing on such topics as wage changes, hours of work, cost of living, profit-

sharing, trade union agreements, works councils and other subjects in which manufacturers as a whole are interested. In addition, many of these thirty constituent national associations of manufacturers carry on research activities of more particular interest to their respective special fields. Supplementing this direct effort by business men themselves are such private enterprises as business forecasting, advertising or marketing bureaus, and the like, which sell the results of their researches in summary or graphic form to business men.

In the past few years the research idea has taken firm hold upon American industry. Business is endeavoring in innumerable ways to solve its problems by getting at the facts.

In this respect business is, also, coming to look more and more to the third center of research activity mentioned, *viz.*, the universities and other privately endowed institutions such as the Institute of Economics in Washington or the Bureau of Economic Research in New York. The most significant development in this direction has been the establishment of university bureaus of business research, some eighteen to twenty in the past four years. Some of these, such as the one conducted by New York University, engage in research solely *for* business and are financed through the payments for services rendered to their clients. Other university bureaus cover only that phase of business research we have designated as research *about* business. Still others, and notably the Harvard University Bureau of Business Research among them, carry along side by side both research for business and research about business. The Harvard Bureau has had such a remarkable development that a brief statement concerning it is in place here, both for the purpose of making the distinction between the two types of business research more clear and as typifying the astonishing growth along such lines in recent years.

Starting with a gift of $5,000 five years ago, the Harvard Bureau of Business Research now requires an outlay of something like $200,000 a year. The bureau is subdivided into three divisions, one of which carries on the administrative work. A second division is engaged in making research studies for certain wholesale and retail trades. The third division started three years ago on a small scale to make research studies about business for teaching purposes, through the preparation of selected business cases. The method proved so successful that during the past year this division had from twenty to thirty field agents engaged in the collection of business cases, in addition to the necessary supervisors and clerks in the central office to put the data into proper form as they were sent in.

A word should also be added regarding cooperation between the government, business and the universities in respect to business

research along certain lines. Within the past few weeks announcement was made through the press that research agencies and corporations in twenty fields were in process of combining their efforts, under the auspices of the Personnel Research Federation, "to weed misfits out of industry and to make its millions of workers happier, more efficient and more productive"—to quote from the announcement.

So much for the extent and the rapidity of growth of modern business education and research and the content of business research activities. We have still to examine more fully into the content of the business courses offered in our schools and colleges, in which connection the relation between business research and business education may be indicated. Regarding this relationship one can not do better probably than to quote from a recent report of President Burton, of the University of Michigan, in which he says:

> Research is a primary function of a true university. Only as scholars in every field are making contributions to our knowledge of the world, and only as mankind gradually but surely acquires a mastery of the universe, have we reason to hope for that progress upon which civilization rests. Moreover, it may be said with some show of truth that the teaching efficiency of a university is intimately related to its research activities.

President Burton's statement holds no less in the field of business education than it does in any other field of education. One can not hope for high-grade business courses unless these are based upon business research, and that is precisely what the Harvard method of collecting business cases is providing. Just as the case method of teaching legal principles put the law school upon a solid basis, so the case method of teaching business principles is raising the caliber of courses offered in the business school. Thus business research is aiding business education. In place of the descriptive matter in the ordinary text-book on business subjects, the book of business cases provides thought-provoking material for the student, prepares him for dealing with the kind of problems he will actually face in the business world, and, finally, through the care with which this case material is being assembled, gives him a thorough grounding in the broad fundamental principles of business. And at the same time that better instruction material is being provided by such agencies as the Harvard Bureau of Business Research, better equipped college teachers are being prepared in such institutions as the Harvard Graduate School of Business Administration, which, as we doubtless know, has recently been given a donation of $5,000,000 by a prominent New York business man for the purpose of expanding its work.

In spite of these advances, however, there is still much to be done in the matter of curriculum building. In the first place, as has been intimated at the outset, the content of collegiate business courses is not always up to college grade. In some instances, the courses offered are hardly more than high-school courses. In other instances, courses are offered in some particular form of business, such as the manufacture of textiles or the administration of trust estates, whereas the chief aim should be to provide training in those fundamentals which are common to all business. H. S. Person, in discussing the work at Dartmouth in 1920, pointed out certain standards in this respect. He said:

> During the more than fifteen years of our efforts at the Tuck School, we have been searching for the elements of a curriculum which are basic in the sense that they relate to elements in business which are universal in all business. We have come to believe that the differences between businesses which are ordinarily noted—that one manufactures or distributes shoes and another sugar; that one fashions or deals in tangible commodities and another offers services—are superficial from the educational point of view. Attention to these differences is essential, but too much should not be made of them. A curriculum, the elements of which are determined by a consideration of these superficial differences, is likely to develop limitations in the graduate rather than give him professional freedom and power. Have you ever considered the fact that it is an exceptional student who knows until the time of graduation what business he is going to enter, and that the businesses most students enter are determined largely by the opportunities presented at the last moment; also that five years after graduation the majority of graduates are no longer in the businesses they entered at graduation? These are significant facts. The inevitable conclusion is that the object of training for business should be the development in the individual of universal and transferable professional business ability. That alone will give him freedom and power and make him master of his career.

In the second place, so-called collegiate schools of business are themselves of differing grades. Certain schools, situated chiefly in large cities, offer a collection of business subjects, especially in the form of evening courses, to meet the immediate practical needs of the business world. Such schools render a definite service, but their aim is quite different from the aim of the collegiate schools which put their business courses upon the same plane with liberal arts or similar broad disciplinary work, and offer a course leading to a bachelor's degree.

Speaking of the standards a collegiate school of business should maintain, Dean Hotchkiss summed up the matter four years ago as follows:

(1) Business education must be considered, not as a thing in itself, but as part of the whole scheme of higher education;

(2) Schools of business are related to a college or university precisely as schools of law, medicine or engineering are;

(3) Such schools must have a professional aim, and furnish a basic mental discipline and a broad outlook regarding the principles of business.

Viewing the business school curriculum in relation to other work offered in a university, it is, of course, obvious that the course in business must be grounded in the work of the liberal arts department of economics. Furthermore, liberal arts requirements in the fundamentals of language, exact science and other social sciences besides economics must be maintained to provide broadness of outlook. In the department of economics, in addition to the general course in principles where the organization of industrial society is broadly indicated, courses should be offered, for the election of the student of business, in banking, transportation, trade, agriculture, mining and manufacturing; and the course in business principles, forming the basis of the student's technical training, should start with a résumé of these broad subdivisions of the economic structure.

The technical training of the business student may be thought of as beginning with an examination of the economic structure from the standpoint of the individual business concern. Various forms of business concerns, such as the proprietorship, partnership and corporation, are first analyzed, after which they are examined in the light of the broad functions the business man exercises, *viz.*, organization, coordination and administration. From another angle these functions may be regarded from the standpoint of ownership and control on the one hand, and business management on the other hand.

Business ownership and control involve the exercise of the organization function and the determination of the larger policies of a business. Here the broad problems of banking, transportation and of the other advanced economic courses should be summed up in their bearing on the formation of business policy. And this should be supplemented by courses in business statistics and the forecasting of business conditions.

Business management involves the exercise of the functions of coordination and administration and the carrying out of the broad policies laid down by the owners. This means a study of the main subdivisions of business management, such as finance, production, sales, personnel, accounting.

Such a course of study, covering both liberal arts and technical business subjects and providing a broad training rather than a detailed knowledge of some particular business, is the ideal to which collegiate business education is endeavoring to measure up.

But it can not fully measure up to this ideal (as has been said), until a sufficient supply of business case material has been pro-

vided, and until a sufficient number of properly trained teachers have been secured, not only for collegiate business education but for secondary business education also. Both these needs are now being filled.

We must hurry on from this somewhat cursory résumé of the extent and the content of modern business education and research to causal considerations. What circumstances have occasioned this rapid and unprecedented development? The answer is not far to seek. It is bound up with recent developments in industry.

The first fruits of the industrial revolution, *viz.*, factory production and the application of pure and applied science to manufacturing pursuits, created a need for technically trained men and for research as applied to technical production problems. This occasioned the rise of schools of engineering and technology. Beginning in 1824 in this country, isolated technical schools began to spring up, and after the Civil War this movement was stimulated by grants from the federal government. By 1915, 67 institutions of this nature, with 69,000 students, were in existence. Since the World War, there has been a still further increase. The technical production problems of industry are being solved in a most satisfactory manner.

But the industrial revolution also brought other results in its wake—alternating cycles of business prosperity and depression, banking crises and panics, transportation problems, wholesale paralyses of business through organized strikes and lockouts, more intense competition for markets—in short, an ever-increasing uncertainty, which came to plague the business man and which the solution of production problems only served to augment.

At first business men, the public, the government and even the economists were not aware that anything could be done to remedy these difficulties. But with their growing complexity, a realization finally broke upon all concerned that distribution problems, just like production problems, were subject to better understanding and at least partial if not complete solution. Thus research and education came to be applied anew with the results already indicated. Schools of business and bureaus of business research have come to the fore.

The modern business man is, on the one hand, demanding executives thoroughly grounded in an understanding of these broader business problems; and, on the other hand, he is insisting that facts regarding business conditions, marketing possibilities and the like be placed at his disposal.

The public has also become interested in these newer developments as they touch the public welfare, and has set about studying them through duly constituted governmental agencies. Unemploy-

ment, profiteering, tariff changes, speculation and like problems are followed with keen interest through the daily press, and this interest has been augmented by reparations and other post-war difficulties. This interest has drawn many young people to take up the study of economics in our high schools and colleges, while the lucrative rewards that come to successful business men in a country of free business enterprise has caught the imaginations of those preparing themselves for a life's career.

And last but not least is the better understanding of business problems on the part of economists themselves. Better and more readily understood texts are being written. Introductory courses are being given in our secondary schools. Economics has finally lost the stigma of the "dismal science" fastened upon it in the classical period and has become a fascinating field of study for many.

We come now to the last phase of the subject under discussion. What lies in the offing? What does the immediate future hold forth in respect to business education and research?

To the speaker this future looks promising in two directions. In the first place, it appears that the art of business and the science of economics are finally being placed upon an exact scientific basis. This should mean that our most insistent industrial problems will be brought much nearer to solution. It is facts and a scientific interpretation of facts which makes men free; and business men are clamoring as never before for facts. And the facts they are now seeking are basic for the science of economics. Facts about consumer's wants, facts about demand, facts about supply, facts about crops and prices and personnel and sales and advertising and markets and periods of boom and depression and about a hundred and one other problems that lie at the very heart of a proper understanding of economic principles. An economist can hardly be accused of ulterior motives when he says of his own field of study that it is not yet on a scientific basis. Such is precisely the speaker's position. Economics is still astonishingly shy of basic facts. Many theories still put forth have had no adequate testing out But now that testing period has come. Business facts are being accumulated on all sides. There is no reason now why economics should not have as rigid a foundation as has biology or chemistry.

For this, however, something further is required beyond the mere gathering of facts. It requires comparison, interpretation, the formulation of general principles. Towards this end there are also hopeful signs. One is the growing suggestion that business research efforts be coordinated. Toward this end, the U. S. Department of Commerce is now carrying on a survey of existing business

research agencies and has constituted itself a clearing house for the exchange of business information. That such agencies are beginning to cooperate with one another was brought out quite clearly at the last annual meeting of the American Association of Collegiate Schools of Business held in May, 1924, in New York City. At the same meeting Chancellor Brown's suggestion that the time was ripe for the establishment of "great libraries of commerce and industry in which all manner of business research can be successfully prosecuted" was met with a hearty response from the delegates.

The second direction in which the future looks promising lies in the creation of better professional standards for business. Last May the U. S. Chamber of Commerce, representing some 1,300 local trade bodies, with an underlying membership of several hundred thousand business men, adopted a code of ethics for business, which is now before the various local bodies for their ratification. This action has led certain enthusiasts to take the position that forthwith business is being raised to the same professional plane that medicine, law and engineering are on. But what is apparently being overlooked in drawing such a conclusion is that the mere adoption of a code of ethics (as laudable a step as that is) has not placed the professions on the plane they occupy to-day. Medicine had its code of ethics laid down for it by the great Hippocrates over 2,300 years ago, but this did not prevent scandalous and widespread malpractices. Finally, society was forced to take the matter in hand and set the standard for admission to practice; and it is these standards, revised from time to time, which constitute the professional standards for medical practice to-day. Society has also set professional standards for the practice of law and is in the process of setting them for the practice of engineering. Broadly speaking, these professional requirements consist of a college degree in medicine, engineering or law, the serving of an interneship or clerkship or something similar, and the passing of examinations or other community tests.

The business man is exempt from any such requirements. The effect of such standards, socially set and rigidly enforced, is to automatically exclude the worst of the charlatans and the unfit and to secure the confidence of the public in those who are admitted to practice. As a result, society can expect more from the professions than it can from business as it still is. In spite of the ever-recurring crop of shyster lawyers and quack doctors and a certain deplorable professional secrecy, we have come to expect fine things from doctors and lawyers and are shocked when they fail to measure up to expectations. Business, however, is not as yet regarded from the same angle. We say "business is business" and we imply nothing complimentary by that phrase.

A code of ethics for business, comparable to the codes already in use by the medical, legal and engineering professions, has been advocated in many quarters for a number of years. The public has just about got enough of the predatory slogan of "business is business," and the pressure of public opinion has undoubtedly helped to secure the recent action of the Chamber of Commerce, though there are many high-minded men in the business world who are just as impatient with predatory business methods as the public is. Society is asking itself why it should expect less from the business man than it requires of the doctor or the lawyer or the engineer. It is wondering if professional men affect the lives and destinies of their clients any more than the business man affects the lives and destinies of his employees, not to mention the consumers. The adoption of a code of ethics, as important a move as that is, is not enough. If business is to be placed upon a professional basis, standards must also be adopted and enforced.

It is conceivable that business will raise itself to a professional plane without the intervention of society, but whether professional business standards are set voluntarily or forced from without, the requirements must undoubtedly be the same as they already are in medicine, law or engineering, *viz.*, a certain educational background (usually covered by the securing of a college degree) or the passing of certain technical tests or both.

Business research will undoubtedly aid in raising business standards, for as the facts about business become more fully and generally known, it will become more difficult to engage in questionable practices. But by far the greater influence in this direction is collegiate business education.

In this connection Professor Lyon, in his book on "Education for Business," makes the following carefully guarded observation:

> The collegiate school of business has justified itself if it has improved production and organization, and perhaps it can not do more. The field of the collegiate school of business may be limited to improvement in technique and in organization. If this is the limit, however, it is unfortunate. It will be regrettable if the collegiate school of business can not develop a corps of business men capable of guiding society. It will be regrettable if the collegiate school of business can not place clearly before its students the underlying assumptions of a business world; if it can not bring its students to see that captains of industry are as much needed properly to place business and to limit it, as they are to employ it and exercise it. Only with some such objective can the study of business in any sense apply to itself the notion of a profession [pp. 390–1].

We may add to Professor Lyon's observation that there is no reason why a liberal arts background and a thorough training in principles can not do for business what it has done already for

medicine, law and engineering. In the United States more than 4,000 college degrees are now being conferred annually in the field of business education. Many of the recipients of these degrees will be leaders in the business world in the years to come. Thus side by side with the sordid double-dealing of the market place and the spirit of the devil take the hindmost, we are already finding the collegiate spirit of *noblesse oblige* and the vision of the future based upon a contact with our highest social and intellectual heritage as it is secured through a liberal arts education. In this respect, collegiate business education has a high mission to fulfill.

EMPLOYE REPRESENTATION

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NOTHING is more obvious to the reflective mind to-day than that the whole concept of conflict needs thorough revision. The struggle concept is an old one. Biology has long since familiarized us with the idea of the "survival of the fit" through conflict. Youth and old age are forever in conflict. In our industrial life a deep-seated, persistent feeling is very generally voiced, that there prevails inevitable conflict—conflict between employer and employe; between producer, middleman and consumer; between banker and manufacturer; between merchant and merchant; between worker and worker. The state is the arena in which social welfare arises from the battles of conflicting interests. The entire technique of justice, as carried out in our courts, is a regularized conflict technique, designed to bring about a judgment that will "close" the controversy. The church is divided through conflict—fundamentalist arrayed against modernist. The whole world is in a state of conflict; religion set against religion, race against race, nation against nation.

Now no phase of this universal conflict-state is more vital to us all than the economic conflict, more particularly that aspect of it observed at the centers of the productive processes—the conflict between employers and employes. Society is dominated by a machine technique. The deepest feelings, both noble and ignoble, surge around and through the economic forces. "The economic relations are all comprehensive enough to include both heaven and hell." Here we need new incentives, new solvent concepts, great industrial statesmen to lead us into the light and harmony of a new industrial day.

At this point let me interject a few quotations:

The great tides of the world do not give notice that they are going to rise and run; they run in their majesty and overwhelming might, and those who stand in their way are overwhelmed. The forces of the world do not threaten, they operate.[1]

Science and religion, the elder brothers of social life, must draw closer together in cooperative social action; science absorbing the more hopeful and spiritual qualities of religion, and religion the more progressive and frankly intellectual qualities of science. Every phase of man's education must emphasize the creative law of cooperative egoism and altruism, or the universal obligation to self-aggrandizement for the purpose of self-giving. This elemental creative law is the fundamental lesson of social life. Unless it is well learned, forming a basic part of man's personal character and of his social institutions, his intelligence will be devoid of its most essential human quality, his learning vain, and his social life a failure.[2]

Somehow, if progress is to be made, new codes of action must be drawn, under which the difficult adjustment of individualism to group responsibility shall be shown to be practicable and in which the two motives shall be blended. No greater challenge can be issued to the college in its capacity as representing the world of education.[3]

The most natural bond between individuals is that of cooperation in a common enterprise.

An association, to be vigorous and effective, must faithfully reflect the will of its adherents and form an intimate part of each adherent's interests. Mankind, as a whole, is instinctively communally-minded. Industrial management is thereby presented with the opportunity of making the factory rather than the class the basis of association.[4]

The gradual development of the equality of conditions is a providential fact, and it possesses all the characteristics of a Divine decree: It is universal, it is durable, it constantly eludes all human interference, and all events as well as all men contribute to its progress.

The first duty which is at this time imposed upon those who direct our affairs is to educate the democracy; to warm its faith, if that be possible; to purify its morals; to direct its energies; to substitute a knowledge of business for its inexperience, and an acquaintance with its true interests for its blind propensities; to adapt its government to time and place, and to modify it in compliance with the occurrences and the actors of the age.

A new science is indispensable to a new world.[5]

As a result of gradual evolutionary processes, advanced industrial countries are coming under the influence of a law as pervasive, comprehensive and dynamic as any of the laws of physics, chemistry or metaphysics. This law has been discerned by a few far-sighted

[1] Woodrow Wilson.

[2] W. Patten, "The Grand Strategy of Evolution."

[3] President Ernest M. Hopkins, annual address to students of Dartmouth College, 1924.

[4] Oliver Sheldon, "Philosophy of Management."

[5] A. DeTocqueville, "Democracy in America."

statesmen. President Wilson had it in mind when he declared that "great movements do not threaten, they operate." But this law has not been comprehended by the vast majority of men whose lives it is reshaping and whose future it is definitely to revamp more than any other force now operating in society.

I believe this law to be a law of nature, based on her constructive, cooperative processes of evolution, her biological law of egoism and altruism, of give and take. This law I would state as follows: *Power with increasing momentum is passing from the few to the many.* This law emphasizes the great necessity for group loyalty and group solidarity.

The full import of this principle is only understood by comprehending the scientific data gleaned from biology, physiology, psychology, economics, politics and ethics, revealing the organic life processes of the physical, intellectual and spiritual unity of mankind. The world, and particularly industry, is in chaos to-day largely because man's organic nature is not thoroughly understood. What some recent psychologists call "the total situation" in which man moves has not been duly conceived, observed, analyzed, evaluated. Man's work relations and his life ties have been regarded too much as incompatible, rather than as interpenetrating influences. The intimate interrelation between man's habits of thinking and his habits of doing has not been adequately understood. We have not taken a conscious, deliberate, responsible organized attitude toward our total daily experiences. President Hadley recently called attention to this lack in developing all-around personality, due to the overemphasis placed on the distinction between learned and unlearned occupations. He stressed the necessity of professional training in the telling qualities of observation, accuracy and self-reliance: for knowledge is power only as it is combined with self-reliance in thought and action.

In the October, 1924, issue of the *Yale Review,* Mr. L. P. Jacks very wisely emphasizes the absolute necessity of so understanding, organizing and directing future industry that the masses of mankind may literally get culture therefrom. To Jacks "education is the process of training the industry of man, in its manifold varieties and in its organized totality, to the highest pitch of excellence it is capable of attaining. The only type of education appropriate to an industrial civilization . . . will have its roots in the actual labor of mankind and will return into that labor to endow it with higher qualities and more valuable aims."

Many significant consequences flow from the redistribution of power now taking place in our economic and social life. Among these the most far-reaching, for our purposes, are the following:

(1) The pressing need for the spread of organized, consciously directed education. One of the wholesome effects of the employe representation movement is the spread of economic intelligence. These joint arrangements force the essential facts bearing upon a given situation into the consciousness of those whose lives are most directly affected by them. The daily work experiences thus become a dynamic reality.

(2) This law of the growing equality of conditions, if it is to be directed into wholesome channels, demands a growing appreciation of the importance of the diffusion of property. Professor Carver, of Harvard University, has recently stressed what he calls the evolution of the "labor-capitalist class." Professor Carver believes that we are evolving into an equality of prosperity more rapidly than is generally realized, and that "unless we embark on some unsound policy, the present tendency will carry us further than most of us dream. The processes are now at work under capitalism, under freedom, under voluntary agreement among free citizens, which will put such great power in the hands of our manual and clerical workers that it will enable every occupation to prosper." It is significantly in harmony with the growth of democratic power to know that where employe representation plans have been wisely developed there is a growing appreciation among the rank and file of the significance of this evolution of the "labor-capitalist class." There is a more intelligent interest in saving, a better understanding of the problems of investment, of the significance of stock-ownership and profit-sharing plans.

(3) The redistribution of power flowing from the law stated above is a positive economic and social danger unless we develop with it *capacity* for and *practice* the *habits* of constructive cooperation. In his essay on "Civilization," John Stuart Mill declares that "growth in the capacity for and practice in the habit of cooperation is the surest test of an advancing 'civilization.'" We need a great deal of probing to get at the true principles of group organization, understand the processes of joint control and evolve sound comanagement maxims. If cooperation is to be of lasting benefit, it must become the means of working out an integration of motives and interests, of ideals and standards of justice in industry.

The noted English economist, John A. Hobson, in addressing one of my classes recently, declared that the greatest need of the world to-day is a keener sensitiveness with reference to the sense of justice. Sensitiveness is of the very essence of democracy. The employe representation movement is helping employers and workers realize this fact.

The spread of economic intelligence, the diffusion of property and growth in the habits of constructive cooperation are the strik-

ing characteristics of the democratic law of our times. We are here concerned only with the third of these tendencies—a modest attempt to set forth some of the more significant phases of cooperation as expressed by the employer-employe representation movement. Many influences during and since the war have helped accelerate cooperative arrangements between management and workers. Among these may be mentioned, in passing, the forced determination of shop policy during the war and the influence of governmental operation of industry; open channels of communication as a preventive of costly labor turnover and as a precaution against strikes; joint action as a solvent of ill will and destructive friction; the shortage of labor supply due to restrictive immigration; and a growing conviction that trade unions are here to stay. Among the transforming subtler influences may be mentioned the growth of scientific knowledge. The humanistic sciences are slowly but surely shaping the work relations, humanizing them. Psychology is helping us work out standard methods of measuring and controlling human behavior. It is giving us a more rounded view of life and its organic meaning. We are studying adult behavior in the work relations under controlled conditions. A new business philosophy is emerging—a philosophy demanding that utilities shall be prosocial and brought forth under wholesome human relations. The employe representation movement is among the most significant experiments in our whole economic and social life. It has already, where in operation, revealed a most wholesome influence on the manners of management—on the customs, traditions, habits, opinions and feelings. It has done much to disintegrate prejudice. It is revealing the creative possibilities in conflict.

The employe representation movement is gradually emerging from its experimental stage. It is now entering the stage of constructive accomplishments. Many of the earlier plans, brought forth by the compulsion of the war period, have been modified or have passed away. Many others, born possibly of ulterior motives, have likewise ceased to be. In the main, the plans surviving the rapid post-war development, and the subsequent period of industrial depression, together with those of most recent adoption, are based in major portion upon a more constructive analysis and procedure, upon a clearer conception of the meaning of conflict, upon wholesome objectives. Employers, workers and society are becoming more conscious of the inner meaning of the movement. Both employers and workers now often conscientiously and loyally subscribe to the cooperative principles, technique and goal they have jointly determined. It is helping us understand the aim and significance of a unified democratic life.

Concretely the objects of these cooperative arrangements may be stated as follows:

(1) To provide organization and procedure for collective negotiation regarding hours, wages, working conditions and other terms of the employment contract, particularly affecting the welfare of the workers.

(2) To facilitate organization and procedure for the prompt adjustment of individual and group complaints and grievances—giving special heed to the word "prompt."

(3) To facilitate preparation of subordinates for positions of responsibility by familiarizing them with the needs and demands of the larger managerial problems.

(4) To provide a "double track" channel of communication through which management may learn more about employes' desires and needs and may inform them of its plans and purposes in so far as they are likely to affect the mutual interests of workers and management.

(5) To aid employes to appreciate the difficulties of the managerial function, not only regarding matters of hours, wages, etc., but also policies affecting finance, production, sales and the administration of public relations.

(6) To afford employers, workers and the public an opportunity to find out what they think about their thinking on one of life's most fundamental problems—the human relations in industry.

The earlier doubts, the distrust of the employer's ulterior and secretive motives in creating works councils and fear of workers' radical tendencies are giving way to a wholesome, constructive, mutual confidence and respect. The movement is allying itself with the scientific method, which disintegrates jealousies, suspicions, misgivings, subjective opinions. This tendency to bring the industrial partners to grips at the center of the productive processes is most promising. It is bound to broaden the works councils from the earlier, narrow consideration of problems of hours, wages, working conditions and grievance adjustments to the constructive participation of the workers in the formulation of administrative policies and the solution of managerial problems. The movement is being understood more and more as a growth. Hence methods, technique, means, not ends, are being emphasized. Less time and energy are being given to questions of constitutional form. A smooth, effective mutually satisfying operation is being stressed.

A list of industrial corporations, estimated at above seven hundred, at present operating under some form of employer-employe cooperation would be imposing in length and probably would number 1,225,000 workers, including many of America's leading indus-

trial companies, railroads, etc. Likewise, an inventory of the subjects — jointly analyzed, evaluated and settled by responsible executives with committees of their employes, shows with what sincerity and seriousness management and workers regard their joint arrangements.

Despite the wholesome evidence that progressive managements are convinced that works councils are a constructive aid to sound industrial relations, many questions of policy, principles and technique await clarification before mutually satisfactory results are firmly established. Many problems of a general nature await solution which only time and wide experience can solve. What are the most significant tests for measuring the success of a plan of employe representation? Should the basis of employe representation be the entire system of a company or its separate branches, such, for example, in the case of the railroads, as the train service, maintenance of equipment service, shops, offices, etc.? Is there need to supplement employe representation by some form of extra financial incentive, *e.g.*, stock-ownership, profit-sharing, "economy dividends," etc.? Can trade unions, with their present full-time officials, be incorporated in the employe representation plans, and would such inclusions be desirable? If employe representation becomes well established, what functions remain for the Railroad Labor Board? The solution of many problems will depend upon local situations, such as the composition of the working force as regards sex, nationality, occupation, unionization, etc.

The movement has too often been jeopardized by the common habit of unthinking imitation. It is dangerous in these times for management to move without a clearly defined, freely assented to dynamic creed. A convincing creed should represent clear convictions, sound ideals, workable principles, a tested technique. This, however, does not mean *fixing a goal.* The only safe goal is honest *experimentation* and growth. Definite commitments in this democratic procedure are dangerous. Grave mistakes have been made in this particular. Further, to regard the employe representation movement as essentially a substitute for unionism not only arouses futile destructive opposition, but destroys the opportunity to make of it a constructive instrument furthering the ends of a prosocial production and wholesome, happy human relations.

Unionism itself is doubtless destined to undergo important transformation. An ultimate integration between a new type of unionism and employe representation, though not yet clearly discernible, is, in the judgment of unbiased thinkers, not impossible. In some industries already, for example, some of the railways, and others, certain forms of shop representation and unionism are working side

by side. In these cases there seems to be no mutual hostility. Rather the two aspects of the resulting industrial government have proven reciprocally helpful. Best of all, the contact of the two movements has fostered interest in the problems of production and has promoted industrial efficiency. Certain of the unions of railway workers have joined with the management of the Pennsylvania system to make effective employe representation on that railroad. In many plants, throughout the country, union members have been elected to works councils. At this point many important questions suggest themselves. The attitude of national union officials, whose contact with the employe representation movement has been remote, is often one of direct opposition. What is the attitude of the local union officials who *live* with the movement? What is the attitude of the average union man on the firing line of employe representation toward it? Is he furthering its constructive possibilities or is he opposing it? Has the shop committee movement modified policies or the objectives of unions? Particularly, has it aided them in appreciating the scientific method in shop-practice? Has it in particular instances tended to weaken the hold of unions upon their members? What has been the attitude of union members when elected to works councils? What has been the serviceability of employe representation in bringing to the front the best type of leaders among employes?

These and many other questions of similar nature must be answered on the basis of accurate observation, analysis and evaluation of local facts.

Many sincere employers believe that the employe representation movement affords a more helpful medium than trade unions for joint negotiation to determine hours, wages, working conditions and the settlement of differences arising under the terms of employment. The constant, frequent, friendly contacts between management and workers; the continuous full access to all the facts in a given situation; more intimate acquaintance with the management's desires, actions, habits of thoughts, etc., are advantages which may offset the lesser business experience, freedom of action and broad industrial viewpoint of council members as compared with union business agents. These and other advantages inherent in the employe representation movement may invalidate the claim of some professional union labor leaders that workers unaffiliated with employes in plants of other employers are powerless to gain substantial or permanent advantages from employers. It is a serious matter for an employer to commit his company to the employe representation movement. The purpose of such plans is in order to obtain definite, accurate knowledge of workers' honest desires, just needs,

fair settlement of disputes, etc. Such knowledge the employer counts an asset. Having embarked on this course, the employer must reasonably satisfy workers' demands or furnish adequate reasons for not doing so. To abandon plans entered upon is to destroy confidence in managerial integrity and wisdom and to make more difficult future practice in dealing with workers.

A critical evaluation of the employe representation movement is bringing to light the fundamentals of the human relations in industry. It is significant that there is a conscious, growing conviction that the proper and true relationships between management and workers is not one of continual strife. In the words of General Atterbury, of the Pennsylvania System: "The underlying foundation is that the mutual relationship is one of harmony and accord and is conceived and carried out on the threefold basis of mutual faith, facts jointly established and fair play."

DeTocqueville, the master mind of democracy, long since declared that "whatever exertions may be made, no true power can be founded among men which does not depend upon the free union of their inclinations." What does this mean for business managers and their employes? Are we not justified in deducing from it the logical conclusion that if we are to have true efficiency and harmony in the work relations, managers and workers, or their representatives, must exercise not superior force, but a right; that authority must rest upon proven worth and wisdom; that obedience will be increasingly rendered, not to a man, but to improved industrial law and to justice?

Are we not coming to recognize that the idea of voluntary agreement among those most interested in decisions at the pivotal point where issues arise is of the essence of cooperation in industry? Is this not the way to open up channels for the free flow of facts, knowledge, hopes, aspirations, wisdom (which cometh from discussion)? Would such a "free union of their inclinations" not tend to awaken and foster at the centers where energy should be developed a keener sense of personal responsibility in workers? Industry needs a more conscious, deliberate, responsible, organized attitude on the part of all its participants toward their daily work experiences.

As stated at the outset, the whole concept of conflict needs thorough revision. Too much conflict is destructive. We must come to think of conflict as a challenge, as life-giving, as an opportunity for creative thinking. If the conflict situation is entered upon with a sincere purpose to use it as an occasion for organizing and integrating thought, will, purpose, rather than as an opportunity for winning a decisive victory over one's opponent, then it may become

a most fruitful stimulus to creative thinking, bringing about a settlement which will result in life's most fundamental satisfactions: scientific discoveries, increased productivity, harmony in the human relations and moral values.

THE ECONOMIC IMPORTANCE OF THE CONSERVATION OF VISION

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To the casual observer as he notes the great army of children wearing glasses, as he reads the reports of various welfare societies that 30 per cent. of our school children have defective eyesight, that 50 per cent. of the men engaged in industry have poor vision, it would appear as if the vision of the people of the present age was rapidly deteriorating, as if there was a great need for some concerted and extensive effort to conserve what vision we have lest we become a country of the blind where the person with good eyesight is considered a freak and undesirable.

It is my intention to bring before you a few facts and figures in order to show you that there never was a golden age of vision, and that if glasses were much less in vogue 100 years ago than they are to-day, it was not because they needed them a bit less but rather because they were not so aware of their needs.

Statistics on blindness have been gathered extensively and by very careful observers in many lands, and they show that *everywhere total blindness is on the decrease.* Thus in the United States in 1880 there was one blind person to every 1,032 inhabitants or 49,000 blind in all, in 1890 there was one to every 1,238 persons, in 1910 one to every 1,600 and in 1920 one to every 2,000 or 52,560 in all. Nor is it difficult to understand this when we analyze the causes that induce blindness.

Previous to 1880 a survey of the inmates of the Blind Hospitals and Homes of Europe and America disclosed the fact that 25 per cent. to 30 per cent. of the blindness came from a single disease, a disease contracted at birth within the birth canal and of such virulence that it speedily destroyed the delicate cornea, leaving the eye irrecoverably sightless. With the advent of bacteriology and the discovery that a simple remedy, even mere cleansing of the eyes at birth, if used, would prevent this inflammation of the eyes of the newborn, an almost immediate reduction in blindness from this cause was obtained all over the civilized world, and to-day less than

4 per cent. of the blind owe their affliction to this cause. In fact, in the largest maternity hospitals in the world the disease is a rarity and all because nurses and doctors are taught to consider every newborn babe as possibly infected and to use cleansing solutions and antiseptics as a means of prevention.

Again, it was estimated that 35 per cent. of the blind in the days before Jenner, *i.e.*, in seventeenth and eighteenth centuries, were made so by smallpox. Smallpox was as prevalent in those days as measles in our time and thousands lost the sight of one or both eyes when the pustules affected the eyeball. In the 11th U. S. census 1 4 per cent. of the blind attribute their blindness to this disease and even in 1920, among some 26,000 cases of blindness from all causes, smallpox is responsible for 230 cases. In eastern countries, where smallpox is still virulent, blindness from this disease is not infrequent. In Mexico, Ruiz in 1922 reports 20 per cent. of blindness due to smallpox. A third great cause for blindness of former years, and the blindness in several tropical countries to this day, is a contagious disease of the lids known as trachoma and as Egyptian ophthalmia and granular ophthalmia.

During the great famine in Ireland nearly 87,000 persons were treated in the workhouses, suffering from this malady, and it has afflicted large armies and navies wherever crowding occurred. Even in the World War, due largely to the influx of Chinese soldiers, over 5,000 British soldiers were rendered temporarily blind by this disease. Its contagiousness was not known until the nineteenth century. Discovered among the school children of New York City a few years ago it was energetically combatted by the treatment of all affected children and successfully kept from causing serious damage. In some of the southern rural districts this disease has been treated by the United States Public Health Service.

The immigration authorities refuse admission to any one showing even mild degrees of the disorder and in this way trachoma has been almost stamped out of the United States. At least it is no longer a factor in causing blindness among our people.

Thus three great causes of blindness prevalent one hundred years ago have been fairly well placed under control and need not play any conspicuous part in the statistics in the next fifty years.

About the year 1866 a German oculist, H. Cohn, of Breslau, made some studies among school children and showed that nearsightedness (myopia), was common in the higher classes and of increasing frequency from lower to higher grades. This was the beginning of medical inspection of school children. Dr. Cohn advocated many changes in the lighting of schoolrooms, size of desks, size of type and kind of paper in order to prevent nearsightedness,

which seemed to affect 50 per cent. of the children in the high schools.

Myopia in its aggravated form, besides greatly affecting vision in the distance, leads to serious changes in the eye ground and is responsible for some forms of irremediable blindness. Some cases of myopia grow rapidly worse and beyond correction with any strength of lens.

The campaign, therefore, to lessen nearsightedness among school children helped to diminish another cause of blindness and by correcting early in life the slighter errors undoubtedly has done much to prevent the very severe forms of nearsightedness.

Myopia still forms about 16 per cent. of all the defects for which persons wear glasses. But while myopia has not been lessened as much by these efforts as was expected or predicted, a great handicap has been removed from millions of children who without medical inspection would have been obliged to struggle through school life with greatly diminished vision.

Nearsightedness is not all due to close application of the eyes as in school work. It is often found in the illiterate and is often noted in several members of the same family. Some investigators believe it is found more often in some shapes of skull than in others, that there is an anatomical basis for myopia and these anatomical peculiarities are transmitted through several generations, that the sclera of the eye is less resistant in some individuals than in others and permits a stretching or elongation of the eyeball. Therefore, we must not expect to stamp out nearsightedness as trachoma and smallpox have been combatted.

There is another group of eye diseases estimated as causing about five per cent. of all blindness that is clearly inheritable and that with more satisfactory marriage laws might be lessened. Families in which certain forms of blindness are inclined to appear should be made to realize the possibility of such transmission and either avoid bringing children into the world or be bonded to insure the cost of rearing the blind if born. In 1910 it was estimated that hereditary blindness costs the people of the United States two million dollars annually.

The last great factor in the destruction of vision is to be found in industrial accidents. Here, too, we are happy to say that great progress is being made. Industrial accidents, it is estimated, are responsible for 13½ per cent. of the blind. In the state of Pennsylvania in 1923, 600 eyes were reported as permanently blinded through an accident while at work and nearly one million dollars was awarded for this cause. In the metal trades 50 per cent. of all accidents pertain to injury of the eyes.

Through the efforts of the insurance companies and welfare organizations and large employers of labor, preventative measures have been instituted with an almost immediate result in lessening the eye accidents.

Thus in one large factory where over six per cent. of all employes were subject to eye injuries, after six months' determined application of the use of goggles and the immediate treatment of injured men, eye injuries affected only 1.6 per cent. of the employees—about one fourth of the number. Other large companies report a reduction of 75 per cent. in eye accidents where the men are made to wear a protecting goggle.

That faulty vision itself may lead to accident is the belief of some who would urge proper examination of all persons engaged in industry and correction of their defects as a condition of employment. Railroad employees have been subject to this requirement for many years, as it is recognized that a person with faulty vision could not be entrusted safely with a locomotive.

A steel worker who has one blind eye would be in serious danger if the sound eye were injured with a scrap of metal while he was working on some high scaffold.

The better adaptation of men to their work would come from the information gained by an annual inspection of the eyes of workingmen.

That eye strain is responsible for symptoms referable to other organs is a fact attested to by the records of any reliable oculist. That the correction of such eye strain on a large scale in industrial establishments would tend to greater efficiency as well as lessening eye accidents is the claim made by a number of writers on eye conservation. The question of providing proper illumination in order to prevent eye strain has been considered by engineering societies, and here, too, the results obtained in improving illumination have been worth far more than the cost.

Thus while we are told on the one hand that 30 per cent. of our school children and 50 per cent. of the workmen, or approximately 25 million of those gainfully employed, have subnormal vision, we are reasonably sure that there is less blindness in the world to-day than there ever was, that there is less serious eye disease than there ever was, that the visual acuity of our generation is as great if not greater than it ever was and this in spite of the excessive demands made upon our eyes by our twentieth century occupations and amusements.

The fact that our children resort to corrective glasses in greater numbers than did the children of a century ago is no more an indication of poorer vision in the former than is the fact that because

there are 16 million autos in use in the United States an indication that our legs are growing weaker and we are less capable of walking.

We want to continue to conserve vision by every possible method, and we in the profession of ophthalmology are proud of the results so far obtained.

Now the economic importance of the conservation of vision is almost self-evident. A blind person is practically helpless.

The cost to the nation of the blind exceeds 11 million dollars annually or an average of $300 per year per patient. The individual that loses an eye in an industrial accident costs over $1,000 directly, which is a tax on all the people, and indirectly reduces the earning capacity of the individual for the balance of his industrial life. Many occupations are closed to the man with only one eye. Reduction in vision less than complete that may result from disease or injury necessarily interferes with efficiency.

Eye injuries alone, which according to competent authorities form about one tenth of all industrial accidents, cost the country 23 million dollars yearly in the form of compensation to employes for time lost and there is a loss of like amount to the employe, as he never receives full wages for time lost. If by a minimum outlay it is possible to prevent 50 per cent. of the eye injuries in industry, the immediate saving in money and time is considerable.

If the permanently blind are lessened in number by any general measures such as interdiction of marriage of those afflicted with hereditary blindness, cleanliness and antiseptics during childbirth, prevention of contagious diseases during infancy, detection of early errors during school life and inspection of those employed in hazardous trades, the saving can not be measured in dollars alone. Fortunately, such measures are in operation and are proving their worth.

ECONOMIC ASPECTS OF HEART DISEASE

By Dr. ROBERT H. HALSEY
NEW YORK, N. Y.

To attract your attention to the subject of heart disease, which may seem exclusively medical, it is perhaps unnecessary to do more than state[1] that in this country for the past few years it has been,

[1] "Early recognition and economic aspects of heart disease." Read before the Section of Social and Economic Sciences, American Association for the Advancement of Science, Boston, Dec. 28, 1922. Published in *J. A. M. A.* April 7, 1923, Vol. 80, pp. 971–973.

and still is, the greatest single cause of death. It accounts for over ten per cent. of the deaths from all causes. If one considers the monetary value of the losses in labor and life they mount into the billions, and such losses are the more amazing when one realizes that in great measure they are preventable. These losses are a wasteful toll upon the production, distribution and consumption of wealth and thus have very definite social aspects. Not only are these economic and medical phases of heart disease evident, but because they involve appreciable fractions of the population and elements of ignorance, vice, crime and poverty, which the individual unaided can not successfully combat, they may be also considered of importance to the public health.

The yearly loss by death from heart disease is greater than that from tuberculosis or cancer, which for many years have been, and still are, recognized by public opinion as well worth attention.

Though there may be controversy as to whether there is an increasing death-rate from heart disease, there is little doubt that the mortality among white females and in the colored of both sexes is very definitely increasing.

It has been asserted by a careful writer[2] that a child at ten years of age is, under present-day conditions, three times as likely to die eventually from heart disease as from tuberculosis. The disparity between the chances of death from heart disease and from tuberculosis increases with advancing age—more rapidly for females than for males. At age of thirty the male is nearly four times as likely to die from heart disease as from tuberculosis; the females are six times more likely to die from heart disease as from tuberculosis. It is shown, also, that at age of ten one in every five of the living will succumb to organic heart disease.

In 1922[3] it was estimated that the loss in continental United States and Canada would be 180,000, of which 57,000 would be among the insured. This loss is not restricted to old people, for about five per cent. are among children under fifteen years and fully 30 per cent. involve persons under fifty years of age. The average age among insured persons at death from heart disease is only fifty-six years, while at fifty-six years the expectancy is seventeen years more.

The importance of the mortality from organic heart disease has been stated in terms of comparison with the infectious diseases of childhood; thus between one and four years of age heart disease causes one third as many deaths as scarlet fever and one quarter

[2] Statistical Bulletin, Metropolitan Life Insurance Company, November, 1924.

[3] Dr. A. S. Knight, "Life waste in 1922," address at the sixteenth annual meeting of the Association of Life Insurance Presidents, December 7, 1922.

as many deaths as whooping cough. Between five and nine years of age heart disease causes more deaths than do any of the so-called children's diseases, excepting diphtheria, and has a higher death-rate than tuberculosis. Between ten and fourteen years of age heart disease has a heavier mortality than all four children's diseases combined.

From the same source it is learned that between twenty-five and thirty-four years of age organic heart disease causes as many deaths as lobar pneumonia. Between thirty-five and forty-four years of age organic heart disease causes more deaths than chronic interstitial nephritis. After forty-five years of age organic heart disease shows a higher rate than any other cause.

Among insured in the year 1923, it has been shown in one company that 12 per cent. of all policies paid on account of death are for heart disease and in one company alone equals $7,691,000. This figure must be multiplied many times, if the number of large life insurance companies is considered.

If one considers that every year of additional life for an adult means a net increase of $500 to the national wealth, one can build up a pretty sum in economic losses among insured lives; for, if the average age at death is fifty-six years, at which there is an expectancy of seventeen years, one readily shows a loss of at least $500,000,000 each year. Nor does this consider the sorrow and anguish or social losses of the many families broken and dissipated by the death.

That damaged hearts produce a larger toll of death than is directly charged is shown by a study[4] of influenza statistics, from which the inference is drawn that persons whose hearts were weak died when attacked by influenza, while others recovered.

From this brief résumé of the mortality statistics alone it is seen that heart disease is a very potent influence for ill in the national economic life.

Now what is the situation as to the living handicapped? It can be shown that for every death there are about ten individuals with damaged hearts to keep up the supply each year of deaths from this cause. Nor is it only by their deaths that these ten add to the economic loss, but from the gradual, progressive incapacity they are unable to maintain their standard productivity for months or years and, because of this failure, become an added financial and social burden to the family and, directly or indirectly, upon the community as a whole.

Among various groups considered as well—the children of the public schools, young adults of draft age, applicants for life insur-

[4] Raymond Pearl, Public Health Reports 1921, 35, pp. 273–389.

ance—it has been found that approximately two per hundred have hearts damaged by organic disease. It is a conservative statement and well within probability, therefore, to assert that in this country alone there are over two million people with organic heart disease. Of this over 600,000 are children of school age. From work done in the schools of New York it has been demonstrated that most of the children acquire the damage to the heart during the pre-school age and the cause of the damage is most closely associated with the infectious disease best called acute rheumatic fever.

From the data available in the special cardiac clinics of New York City and collected by the New York Heart Association, there was an average of approximately 6,000 individuals attending the out-patient clinics per month, making a total of 35,000 individual patient visits to these clinics in the year. The cost of this care estimated on the average cost per patient attending these dispensaries has been shown to be $23,561. It has been estimated, also, that a proper social service and medical follow-up with dispensary care approximately costs $15 per patient per year, or $88,500 for the group, if receiving adequate care.

From the records of ten hospitals in New York, the cardiac patient required 236,047 days, or 9.35 per cent. of all patient days at these hospitals, but represented only 4.58 per cent. of all patients. The total cost of the care of the patients in these ten hospitals was $607,280.

Those heart patients who were accepted in the convalescent homes cost for the year $156,591.

The total annual cost, therefore, for this one year group of heart patients who reach dispensaries, hospitals and convalescent homes mounts to the sum of $787,432 for one year. From what has been said it is obvious that this sum does not begin to express the total yearly cost of heart disease to the city of New York. If this is the incomplete bill of one city what must be the total cost each year of the care of patients with heart disease for all the cities throughout the United States and Canada?

In these few words we have touched on the losses from early death, from living physical incapacity and diminished productivity; from individual family and community expenditures on account of heart disease, and have shown the yearly sum of economic loss to be very great. The query naturally arises: What is being done and what can be done to decrease this waste of life?

Certain groups of interested persons of New York, Philadelphia, Boston, Chicago and other cities of the United States and Canada have organized and incorporated the American Heart Association for the purpose of making the problem of heart disease an absorb-

ing study. The members of that association recognize the enormity of the problem and that all organized agencies, groups and individuals must be informed of the complexity and intricacy of the problem and the part each must take in cooperation, if a solution is to be obtained. Thus, statistics must be gathered and analyzed by trained workers. Those interested in anatomy, evolution and eugenics must study the cause of defective development of the circulatory system. The student of heredity and hygiene must work upon the so-called degenerative diseases of the heart and arteries. The physiologist must discover the difficulties and interrelation of the internal secretions as they affect the heart. The bacteriologist and chemist must find the cause of rheumatism and the means of cure and prevention. The practicing physicians and clinicians must correlate the work of all and make from the mass of knowledge practical regulations for the improvement of the public health, which, then, may and must be applied by departments of health.

Certain things can be done at once by all persons—chief of which is the task for each person to have yearly at a stated period a complete physical examination by a competent physician. This has been demonstrated to be necessary in order that the presence and type of physical defect may be discovered early and before it gives symptoms; second, that the progress of old handicaps or development of new may be known; third, that advice as to type of occupation or need of change of occupation may be obtained as early as possible to prevent unnecessary incapacity and thereby prolong health, happiness, productivity and life.

Some of the larger insurance companies have already applied this annual stock-taking routine among their insured and have shown that over a period of five years the group had a 28 per cent. more favorable mortality as compared with the entire ordinary department for the same years and gave a return of two dollars for every one dollar expended. If the periodic medical examinations more than pay the companies how much more valuable must it be to the individual and to the community?

It has been shown[5] that by the application of the medical and sanitary knowledge now available the expectation of life in the United States could be advanced from fifty-eight to sixty-five years. What will follow the application of known facts to the prevention of heart defects can only be known by trying them out. To apply known methods of hygiene and sanitation requires wider distribution and dissemination of the knowledge to the professions, departments of health, educated persons and the less intelligent individuals of the population. Improved individual health must be made the

[5] Dr. L. I. Dublin, Harvey Lecture, December 16, 1922.

vogue! It is a matter of the greatest economic, industrial and social conservation, and the American Heart Association is planning to push the leadership in this work, define its objectives, assemble and interpret the basic facts and work out the principles of harmonizing conflicting interests until the public is aroused to such action that will effectively save lives. The more informed the public becomes, the higher will be the standards that will be demanded and the more adequate will be the provisions for public hygiene and sanitation.

Even among highly educated people there is sore need of more knowledge along these lines. Humanity must receive from the medical and scientific professions and from education more of the aid which they are capable of furnishing, and this can only be done by a great united public health effort.

It is the desire of this organization to plan soundly and wisely in this undertaking which must be of such great magnitude and there is offered an opportunity for the great national organizations of the scientific, trained men to assume the leadership in a movement which is quite as important as the problem of tuberculosis at one time was, but is now overshadowed by the much larger problem of heart disease. There is an opportunity to organize the best intellects of this country in various phases of a movement which must not be restricted to any one profession, for it is the business of every person to know his own value as a working machine.

It is this thought I desire to leave with you—heart disease as the leading single cause of death is causing huge economic losses. Such losses are in great measure preventable. An organization is available and desires the assistance of every organized body in the special work peculiar to it to the end that effective means may be applied to prevent and postpone death as well as to increase happiness and prolong life.

THE STATE OF SCIENCE IN 1924[1]

VERIFICATION OF THE THEORY OF RELATIVITY

By Sir FRANK DYSON, F.R.S.
ASTRONOMER ROYAL

IN order to explain the transmission of the undulations of light across space, the existence of a medium called "ether" was assumed. This was supposed to possess properties such as rigidity and elasticity similar to those of matter. When it was found that electromagnetic oscillations (such as we now have in radio-telegraphy) were transmitted with the same velocity as light, the same all-pervading medium was naturally taken as their home.

Many noteworthy attempts have been made to determine by optical and electrical means the movement of the earth through this medium. They all gave negative results, and in explanation Einstein put forward in 1905 the restricted theory of relativity. This theory reviewed our fundamental ideas of time and space; it denied the existence of absolute space and absolute time, but regarded these as dependent on the observer. Einstein showed that a simple relationship held between the measures of space and time made by two observers moving uniformly with respect to each other. This theory was in harmony with the experimental results which had failed to discover the motion of the earth through the ether, and also accounted for the change of mass found by experiment in particles moving with very great velocities. In 1908 Einstein's theory was put in a clearer light by Minkowski, who introduced the idea of the *continuum* Events take place in a four-dimensional *continuum* of space and time and not in a three-dimensional space and a wholly independent one-dimensional time. The relationship between the space and time of two observers moving relatively to one another was shown to be analogous to a rotation of axes in ordinary Euclidian geometry.

EINSTEIN'S LAW OF GRAVITATION

So far the theory of relativity had applied only to systems in uniform motion relatively to one another. Could it be extended to systems in which there is accelerated motion? In Newtonian dy-

[1] Prepared for the Hand-book to the Exhibit of Pure Science, arranged by the Royal Society for the British Empire Exhibition.

namics acceleration is attributed to force. Centrifugal force is regarded as a fictitious kind of force attributable to the rotation of the system of reference, but "gravitational" force as something inherent in matter. Is it possible to explain the latter by the properties of the *continuum?* By an extraordinarily brilliant piece of mathematical analysis, Einstein was led to formulate in 1915 a law of gravitation. In the neighborhood of matter the geometry of the *continuum* differed slightly from that of Euclid. It is not possible to visualize this, but it is analogous to the difference, in two-dimensional geometry, between the surface of a large sphere and a plane. The non-Euclidian properties of the *continuum* manifest themselves as a field of force. This can be illustrated in principle by the deflection of path undergone by a pedestrian who tries to walk in a straight course over the slope of a hill. The deflection is due to the geometrical properties of the slope which may be regarded as a non-Euclidian space of two dimensions.

Einstein's law of gravitation, though entirely different from Newton's in mathematical form as in the ideas from which it arose, gives results almost identical with those of Newton. This is its first merit, for Newton's law of the inverse square has been found sufficient to explain in great detail the movements of sun, moon and planets, procession of the equinoxes, the tides, the figure of the earth and many other phenomena. To the first order then, Einstein's law gives results identical with those of Newton. But there is one phenomenon which has puzzled astronomers since the time of Leverrier. The planet Mercury moves round the sun in an orbit which is, to a first approximation, an ellipse. But closer study shows that the position of this ellipse undergoes a change in the course of time, so that the point at which Mercury is nearest the sun (its perihelion) is not fixed, but is slowly revolving. The greater part of this revolution is duly explained by the attraction of the other planets, but a part is left over—only 40 seconds of arc a century—which had not been satisfactorily accounted for, although numerous hypotheses had been framed. Einstein's law of gravitation took this discrepancy in its stride and accounted for it exactly.

THE BENDING OF LIGHT RAYS

This was an achievement which greatly enhanced the probability of Einstein's law being correct. He accordingly examined it to see if there were other phenomena which would follow from his law, but were not given by that of Newton. He found two. The first of these relates to the bending of light. If light in its journey to the earth from a star passes near the sun, it will be slightly de-

flected in its course, just as a particle of matter would be. He gave the exact amount of this deflection, which is greater the nearer the light passes by the sun. This prediction was verified at the total eclipse of the sun on May 29, 1919. British expeditions were sent to Brazil and to the West Coast of Africa to photograph the eclipsed sun. Seven photographs were taken which showed a number of stars. The observers in Brazil waited for two months, when they were able to photograph the same stars just before sunrise. The photographs were brought home and carefully measured. It was found that the relative positions of the stars had been slightly changed in accordance with Einstein's prediction.

The differences in the relative positions of the stars are, of course, not visible to the eye, as they are very minute. The largest displacement is only one third of the diameter of the star's image shown on the photograph.

The predicted amount of the bending of the light by the sun's gravitation for the stars shown on one of the photographs is compared in the following table with the amount actually observed:

Predicted	Observed
0.32″	0.20″
0.33	0.32
0.40	0.56
0.53	0.54
0.75	0.84
0.85	0.97
0.88	1.02

The observers in Africa were not so fortunate in weather conditions as those in Brazil, but they nevertheless succeeded in verifying Einstein's prediction. At the total solar eclipse of 1922 these results were confirmed by Canadian and Australian and still more by American astronomers.

Displacements in the Solar Spectrum

Another test which Einstein proposed for the verification of his theory is a slight displacement in position of the lines in the solar spectrum. The exact position of a line in a spectrum may be considered as measuring the time of some particular vibration in the atoms of the substance the light of which is being analyzed. According to the theory of relativity, the time of vibration of an atom in the sun will be lengthened slightly by the effect of gravitation. If, then, the position of the iron lines in the solar spectrum, due to iron vapor, for example, are compared with the position of those arising from the light of an electric arc with iron poles, they should be found to be shifted very slightly towards the red end of the spectrum.

The verification of this consequence of the theory of relativity was a matter of considerable difficulty, because there are many causes which produce slight displacements in spectral lines. Of these the effects due to possible movements of the solar gases were the most difficult to eliminate. Motion effects due to the sun's rotation and to the earth's rotation and varying distance from the sun are well understood, and could readily be allowed for. There was, however, a puzzling difference in the displacement in different parts of the sun's disc, the observed shift of the lines increasing from the center towards the solar limb, where it was found to be in excess of Einstein's prediction. To determine the cause of this involved measuring the shift in light coming from the hidden face of the sun, as reflected to us by the planet Venus when near superior conjunction (behind the sun). In addition to effects due to motion, the positions of spectrum lines depend to a small extent on the pressure and on the electrical conditions of the gas from which the light comes, also on the effects of anomalous refraction if the gases have an appreciable density. This complicated problem was attacked by several astronomers.

Mr. Evershed, the director of the Indian Observatory at Kodaikanal, made a very complete investigation. He found that the lines in the solar spectrum did, in fact, show a displacement, and he came to the conclusion that this displacement was for the greater part that predicted by Einstein, the disturbing effects, due to pressure, etc., being according to his researches negligible. His conclusion has since been confirmed by Dr. St. John, of the Mount Wilson Observatory, who has not only verified the relativity prediction, but has given an explanation of some shifts of the lines in excess of the Einstein effect. These residual effects had also been noticed by Evershed.

THE ORIGINS OF WIRELESS

By Sir RICHARD GLAZEBROOK, K.C.B., F.R.S.

In seeking the originators of radio-communication, the men who discovered electricity and investigated its fundamental properties are apt to be overshadowed by those who are concerned rather with the development of the art as we know it to-day. Many would be content to mention the names of Hertz, who in 1887 first produced and measured the wireless waves predicted twenty years earlier by Clerk Maxwell; of Lodge, who a year later showed at the Royal Institution some of its effects; of Marconi, whose inventions have done

so much to forward its practical use, and of Fleming, who first investigated the properties of the rectifying valve.

These are great names in the growth of radio-communication, but tribute should also be paid to those who made this growth possible. To find them we must go back many years, centuries in some cases, to investigators who, driven by their love of discovery and impelled by their thirst to know, sought, not to discover wireless telegraphy, but to improve our knowledge of nature and to bring under the realm of law and order some of the strange happenings which their search so led them to note.

Amber, found chiefly on the shores of the Baltic Sea, was much sought for in early days, recently an interesting dissertation on the trade routes of the ancient world has been written based on the dispersion of amber. About 600 B. C. it had reached Asia Minor, and Thales of Miletus is said to have been the first to observe its property of attracting light bodies to itself when rubbed. Thus we derive the name "electricity" from the Greek word for Amber.

It was probably at a later date than this that the curious property of a stone found in Magnesia was first noted, at any rate in the western world, when it was observed that if freely suspended it always set itself in a definite direction. It gained the name of the leading stone or loadstone, and this property formed the basis of the science of magnetism. Tradition tells us that the Chinese knew of this property centuries earlier.

Modern knowledge both of electricity and magnetism dates from Dr. Gilbert, of Colchester, physician to Queen Elizabeth, who in 1600 published his great and interesting work "De Magnete." Gilbert studied only electricity produced by friction; the electric current was still unknown, and for nearly 200 years remained unknown until Galvani, at Bologna in 1786, observed the convulsive shock produced in a frog's leg—at first when it was connected to a frictional electrical machine, and then in 1786 when two dissimilar metals, iron and copper, were placed in contact with nerve and muscle, respectively, and were then made to touch. His observations were continued and extended by Volta at Pavia, who showed in 1800 that the electricity originated at the contact of the metals. This led him to the discovery of the voltaic pile and the construction of an electric battery.

Various workers from Gilbert onwards had surmised that there must be some relation between electricity and magnetism. The verification of this is due to Oersted, professor at Copenhagen, who in 1820 showed that a wire carrying a current held near a magnet caused the magnet to move. Oersted's great discovery was at once repeated by Ampère in Paris, and he, by the aid of a few brilliant

fundamental experiments, discovered the laws which govern the mutual reaction between a current and a magnet. About the same time Faraday, at the Royal Institution in London, pursued the matter still further, and laid the foundations of the science of electromagnetism, the basis of all electrotechnical applications of to-day.

Meanwhile in Germany G. S. Ohm was at work. Volta had shown in 1880 that electrical force or "electromotive force" was produced in his battery, and that when the two metals which constitute its two poles are joined by a wire, a current of electricity flows round the circuit. It was left for Ohm to state the relation between the current, the electromotive force—or electrical pressure—producing it and the resistance of the circuit. Meanwhile, in America, Joseph Henry had during the same period discovered for himself many of the fundamental laws of electromagnetism.

These men, scattered throughout many lands, yet inspired by the same end—the improvement of natural knowledge—were the founders of modern electricity. When, therefore, some sixty years ago, a body of English men of science, led by Lord Kelvin, realized that the time had come to consolidate their knowledge into a system of accurate measurement, they found that new ideas needed definition, new units and standards required names, and with one consent they agreed to give to these standards the names of the great men whose labors through the centuries had wrested from nature the secret of electricity and magnetism. Thus we have the ohms and volts, amperes, henrys and farads which now form part of our daily language.

On the work of the men whose names are thus commemorated is based the discoveries of those brilliant workers who have made it possible to girdle the earth with a wireless chain depending on two or at most three great stations.

Foremost among those associated with modern developments is Clerk Maxwell, who in 1865 read before the Royal Society his paper on "The equations of the electromagnetic field." It was an attempt, which has stood the test of time, to apply mathematical reasoning to those principles, enunciated by Faraday, on which the construction of generators and motors, transformers and practically all electrical machinery is based. This reasoning led him to the result that the effect of changes in an electric current in a conducting wire would be propagated through space with a speed depending on the two constants, inductive capacity and magnetic permeability, which define the electric and magnetic conditions of the medium surrounding the wire. The values of these constants for air can be found from electrical considerations, and hence the velocity with

which electromagnetic disturbances are propagated can be calculated. To quote Maxwell's words: "We now proceed to investigate whether these properties of that which constitutes the electromagnetic field, deduced from electromagnetic phenomena alone, are sufficient to explain the propagation of light through the same substance," and his conclusion is: "The agreement of the results seems to show that light and magnetism are affections of the same substance, and that light is an electromagnetic disturbance propagated through the field according to electromagnetic laws."

Maxwell found that when the calculations were made the resulting value for the velocity was approximately equal to the velocity of light. The work was extended in his "Treatise on Electricity and Magnetism," published in 1873. The values of the velocity of light and the velocity of propagation of electromagnetic waves were not known then with present-day accuracy, and he concludes that they are quantities of the same order of magnitude. Present-day figures show that they are identical, and the electromagnetic theory of light is universally accepted. Nor was the result true only for propagation through air or interstellar space; such observations as were then available showed that, in all probability, it held for all transparent media, though there were discrepancies, known now to be due to dispersion, which required explanation. But there was a wide gap between this theoretical deduction of Maxwell and the wireless telegraphy of to-day, which needed many more investigations in "pure" science before the bridge was complete. No one had received electromagnetic vibrations—at any rate, to his certain knowledge. The method of generating them and the means for measuring them were still to come.

For the former we have to go back to a remarkable paper of 1853 by Lord Kelvin. Helmholtz seems to have been the first to conceive that the discharge of a condenser through a wire might consist of a forward and backward motion of electricity between the coatings—a series of currents in opposite directions. Lord Kelvin took up the question mathematically and investigated the phenomena. He showed that, under certain conditions, there would be oscillations of periodic time $2\pi\sqrt{LC}$, where L is the inductance of the coil, and C the capacity of the condenser. These oscillations must, according to the theory, give rise to waves traveling out into space with the electromagnetic velocity. Fitzgerald had predicted in 1883 that they might be produced by utilizing the oscillatory discharge of a Leyden jar, and Sir Oliver Lodge in 1887 produced and detected them. For their detection the principle of resonance was employed. Any mechanical system free to vibrate has its own period of oscillation, and the application to it of a series of small impulses at inter-

vals coincident with the free period of the system results in a disturbance of large amplitude. So, too, an electric system having capacity and inductance has its own period of electrical oscillation, and, if this coincides with the period of incoming electrical waves, electrical disturbances of a magnitude which can be detected by our apparatus are set up. It is necessary that the receiver and the transmitter should be in tune. Lodge made use of this principle, and, by receiving the waves on wires adjusted to resonance with his Leyden jar and coil, was able to detect them. David Hughes, working in the early eighties, had already detected such oscillations, but was discouraged from pursuing the subject.

In 1879, in consequence of the offer of a prize by the Berlin Academy, the attention of Heinrich Hertz, then a student under Helmholtz, was attracted to the problem of electric oscillations and their detection. He came to the conclusion that with the means of observation then at his disposal "any decided effect could scarcely be hoped for, but only an action lying just within the limits of observation." The investigation was laid aside, only to be revived in 1886 by a chance observation of the effect of resonance in two circuits which happened to be in tune, and his realization of the fact that herein lay the means of solution of his problem. His paper "On very rapid electrical oscillations" appeared in 1887, and from this experiment came verification of Maxwell's theory, the basis of all our knowledge of wireless.

Fitzgerald directed the attention of English physicists to the work at the British Association meeting in 1888, and Lodge exhibited many of the effects of the waves at the Royal Institution in 1889. The investigations which led to such brilliant results were inspired by the desire for knowledge; the idea of their practical application was entirely absent. Signalling by wireless waves was not foreshadowed until Crookes suggested it in 1892, and in 1893 Lodge heard of Branly's coherer and applied it to the rectification and reception of wireless waves. From this started the investigations of many of those whose names as pioneers are familiar to all. But another discovery in pure science was necessary to complete the work.

Edison had shown in 1883 that if an insulated electrode is inserted in an ordinary glow lamp there is a current of negative electricity from the filament to the electrode, and Fleming made some observations about that date on the Edison effect. In 1904 he applied them to produce a valve rectifier for high-frequency oscillations by connecting one pole of his receiving circuit to an insulated plate or cylinder within a carbon lamp, of which the negative electrode formed the other pole of the receiving circuit.

Dr. Lee de Forest improved this oscillation valve a little later, making it an amplifier as well as a rectifier by placing between the filament and the plate or cylinder a grid of metal wire connected to an external source of electromotive force. There is ordinarily a current of negative electricity passing from the filament to the plate —the plate current it is called—through the interstices of the grid. By varying the potential of the grid this current can be varied, and the conditions can be so adjusted that small changes in the potential of the grid will produce large changes in the plate current. The grid is connected to one pole of the circuit receiving the incoming waves, and the small variations of potential which they produce thus give rise to large variations of the plate current which can be made to actuate a telephone and thus to produce audible sounds. By placing a number of valves in series, very large amplifications are possible.

The other uses of the valve are numerous. It is employed as a transmitter for wireless work, while it finds many applications as a source, or rather regulator, of vibrations of comparatively short period. The post office has used it as an amplifier of speech, while Mr. F. E. Smith has applied it as a source of sound in connection with the measurement of audibility.

The whole of this arose from Edison's observation of the discharge of negative electricity from the heated filament, but its development may be said to have been dependent on another and more fundamental discovery about 1897—that of the existence of the electron, the ultimate entity in electricity, which we owe to Sir J. J Thomson.

Before the introduction of the oscillation or thermionic valve, as it is sometimes termed, radio-communication was in practice confined to telegraphy. Signals were sent out and received which were interpreted by the use of the Morse code. The advent of the thermionic valve has made wireless telephony, with its recent remarkable development in the form of broadcasting, a practical proposition and a factor of interest in the lives of innumerable people.

THE PHYSICAL BASIS OF DISEASE

VIII. THE DIAGNOSIS OF DISEASE

By THE RESEARCH WORKER
STANFORD UNIVERSITY

A WEEK later the research worker received a note from the manufacturer:

We're at the St. Francis. Can you dine with us Wednesday? Want you to meet the wife. She's interested in your dope.

"I've been so disappointed in doctors," said "the wife" as they entered the dining room Wednesday evening. "They don't understand my case. Dr. Levison said I was anemic He gave me some medicine, but it didn't do any good. Dr. Blanchard recommended a milder climate. So I came to California; but the climate here doesn't seem to" ———

"Now, Mary," said the manufacturer, "just give me time to order. How about mulligatawny soup? The doctor here ———

"But, you know I can't eat those rich soups."

"Right. Two mulligatawnys, one bouillon."

"My relatives in San Diego took me to Dr. Morello. He found my trouble. The nerve going to the endocrine gland was squeezed. He adjusted my spine, and I was better for a time, but my trouble came back. Then I tried the latest electrical cure. Dr. Langley. He found beginning cancer in my kidneys. He cured this in a few weeks. Lately, I've been eating this new health food. What else is there to try?"

"Why not try a competent medical diagnosis?" said the research worker.

"But I've had a dozen diagnoses."

"You've consulted a dozen practitioners. Various types, various schools. To say the least, the majority of them were frankly incompetent. Do you know the chances of obtaining competent medical advice in California, at the present time? California has nearly 15,000 practitioners. Less than a third of them have ever dissected a human body, or, for that matter, have even seen such a dissection. The chances are two to one that a stranger who doesn't know the ropes will fall into the hands of a man wholly incompetent to determine the nature of his disease."

"A commercial detriment to California," said the manufacturer.

"Conditions here are but little worse than in other parts of the country."

"Then what can be the matter with me?" asked the wife.

"I haven't the least idea. For all I know, you may have a beginning cancer, as Dr. Langley said, that will kill you in six months, in spite of everything science can do."

"Are you serious?"

"Or you may have merely a psychical upset of your organs, because you were not elected president of your woman's club."

"How'd you know I was a candidate?" asked the wife.

"You have a vacuum cleaner at home?"

"The latest model."

"When it gets out of order, I suppose the janitor can easily fix it?"

"Oh, I wouldn't trust him. I telephone the agent."

"In other words, you insist on a competent mechanic to diagnose and treat your vacuum cleaner. Yet you trust your body to any jack-of-all-trades who offers his service. You will excuse me for being uncomplimentary, but it's people of your type, people of means and social position, who're responsible for the commercial exploitation of the medically ignorant. Without your endorsement and support the exploitation would not be profitable."

2

"How did Dr. Morello make his diagnosis?" continued the research worker.

"Wonderful! Soon's I entered his office he said, 'Don't tell me a thing!' Then he looked right through me. 'Endocrine deficiency! Leakage of nerve force! Seventh lumbar!' or something like that. Marvelous!"

"And you fell for such bunk! It's one of our unfortunate heritages from the past, to regard physicians as magicians, with specially developed diagnostic instincts or psychical powers. You don't expect such a thing of an automobile mechanic. You expect him to act like a rational human being. You tell him your trouble. He tests wires, batteries and flow of gas, tries for unusual friction or unusual play of parts, locates the trouble by collecting facts and making logical deductions from these facts. An experienced mechanic may locate trouble quickly. An expert may find trouble overlooked by others. But even the expert claims no special trouble-locating instinct of psychical power.

"The diagnosis of human disease is exactly the same process. Careful examination, logical reasoning. Some physicians are more expert than others. But a physician who makes a grandstand play of his psychical powers of diagnostic instincts can be put down at once as a charlatan interested only in selling himself to his patients.

I care not to what school of medicine he belongs, nor what his standing or previous training."

"We've the same type to deal with in our factory," said the manufacturer. "We weed 'em out p.d.q."

"Probably the most serious criticism of the medical profession to-day is the lack of efficient mechanism for the similar weeding out of incompetents. A young man who passes the elementary state board examination is licensed for life. Within certain limits, he can adopt almost any method of commercial exploitation and be free from legal interference. The dangerous charlatan is not the untrained nature-curist or religious fanatic, but the regularly licensed physician of predatory instincts."

"What percentage of physicians are of that type?" asked the manufacturer.

"Remarkably small percentage, considering the lack of legal control. I believe the predatory instinct is less in evidence among physicians than in any other profession. There are those, however, who deliberately choose medicine as their field of exploitation, deliberately prepare for such a career. A state board examination doesn't test character."

"I should think the public would soon get on to such a doctor."

"The public is often his ardent champion. Let's suppose you, a regularly licensed physician, deliberately plan a career of commercial exploitation. The big money is in a successful new cult. In a popular magazine you find an account of the newer conceptions of atomic structure. Each atom a minute solar system. Central sun, revolving satellites, electrically charged meteors shooting off into space. Strong appeal to popular imagination. You have found your cult. In health the atomic satellites revolve at normal speed. Increase or decrease this speed and you have disease. 'Sick atoms.' The public will fall for it. Each disease has its own atomic rotation. Cancer, tuberculosis, syphilis can thus be quickly diagnosed by electrical tests. The connection between rotation and electricity is not very clear to you, but the public will never notice. Atomic rotation can be hastened or slowed by electricity. Cancer, tuberculosis, syphilis cured."

"The first competent chemist will show this to be nonsense," said the manufacturer.

"The newer conception of atomic structure is not an established fact. No physical-chemist claims it to be. Merely a graphical representation of atomic properties as at present understood. A new fact, to-morrow, may modify this graphical picture. It would take an expert physical-chemist years to disprove your claims.

Meanwhile, your neurotic patients are singing your praise, your machines for electrical diagnosis and electrical regulation of atomic rotation are selling to hundreds of predatory physicians. You may even be fortunate enough to be arrested for fraud. At trial you state under oath that in your opinion your conception of disease is correct. Eminent pathologists state under oath that in their opinion your conception is wrong. A difference of opinion between legally qualified physicians No jury will convict on such evidence. The publicity doubles your sales.''

''A fanciful picture,'' said the manufacturer.

''Exactly the game the late Abrams was putting over in this city. I am told on what I believe to be reliable authority that at the time of his death he was clearing nearly twenty thousand dollars a month with this scheme. I don't know that this was a deliberate fraud on Abrams' part. It's more charitable to assume it was the irresponsible action of an insane man. There's no adequate method of controlling an insane physician. Many a physician has continued practice till the day before he was committed to an asylum. The same is true of the physician who becomes an irresponsible drug addict ''

''A quarter of a million a year,'' said the manufacturer. ''We don't clear that in our Pittsburgh branch. That branch employs over a thousand men.''

'' 'Chicken feed' compared with the sums taken in by the bigger medical fakes. Luckily, the success of such a fake often depends on the personality of its originator. I am told the income of Abrams' institute decreased 90 per cent. within two months after his death. I've no doubt if Abrams had lived his aggressive personality would have won political support. A special board would have been created for the independent licensing of atomopathic physicians.''

''Nonsense,'' said the manufacturer.

''Independent boards already exist in several states to license equally absurd medical fakirs.''

''These alleged fakirs must make cures,'' said the manufacturer. ''Otherwise, they couldn't continue in practice.''

''Then fake oil stock must always earn a fair dividend or it wouldn't sell. There is one born every minute.''

3

''But we're getting away from our original topic. The diagnosis of disease. There is no special diagnostic instinct or psychical power, no magic divining rod. Diagnosis is exactly the same as

locating trouble in an automobile. A competent physician relies solely on logical deductions from determined facts, with careful weighing of possibilities and probabilities.

"I wonder if you realize the difficulties in such diagnosis. There's hardly a symptom that may not be due to half a dozen different causes Few symptoms that can not be merely subjective sensations of psychical origin. The physician must base his judgment mainly on objective data obtained by himself or by competent assistants."

"But doctors treat disease by mail," said the manufacturer.

"No competent physician will attempt a diagnosis solely on the basis of a patient's account of his symptoms. In emergency, a physician may prescribe. He knows he's taking a shot in the dark in doing so Mail-order diagnosis is a common form of commercial exploitation. Often used to sell proprietary products.

"In the first place, serious, even fatal disease may exist and the patient be conscious of no localizing symptoms. Take liver abscess. Local death of liver tissue with local accumulation of pus. One of the most serious diseases Rupture of the abscess often occurs into the heart sac, lungs or abdominal cavity. If unrelieved by surgical means, in nine cases out of ten the patient will be dead in three weeks.

"The liver, as you know, is almost devoid of sensation. Operations may be performed by merely anesthetizing the overlying skin. A liver abscess, therefore, may give no localizing sensation. The patient complains of fever, loss of appetite, occasional chills or sweats. I defy the most skilled physician to diagnose liver abscess from these data. The mail-order physician prescribes for malaria."

"As the disease advances, the patient may become conscious of localizing pain or discomfort. This pain is usually misleading. We are here up against the common phenomenon of referred pain. Sensations arising in one part of the body, projected in consciousness to some other part. Pain from liver abscess is usually first felt in the right shoulder. The mail-order physician prescribes for rheumatism. The chiropractor massages the back of the neck. A religio-therapeutist recommends some ritual. A competent diagnostician inserts a hollow needle into the right side and draws off a pint of pus."

"I have frequent pain in my right shoulder," said the wife.

"Yes. But your pains often jump to the left shoulder."

"You're clairvoyant?"

"Merely a guess. I've been collecting objective data from you since we sat down."

"Liver abscess must be unusually difficult," said the manufacturer.

"Typical of difficulties often met. Another illustration. Tuberculosis of the spine. The bones, as you know, are relatively nonsensitive. They are a frequent seat of tuberculous infection. The center of one of the backbones may be completely liquefied or digested by tuberculosis, and the patient be conscious of no localizing sensations Slight fever, fatigue or exertions, loss of appetite, symptoms that might arise from a dozen different causes.

"As the disease advances, localizing symptoms appear. They are often misleading. Pain referred to the knees or legs. Objective signs even may appear first at the knees. Connected with the backbone are long muscles passing down through the pelvis to the legs. Some of these muscles go to the knees. Tuberculous liquid may ooze out of the backbone into a muscle sheath and trickle down this muscle to the knee. The pus may accumulate at the knee in large quantities, puffing out the tissues. Or it may erode the skin at the knee, giving a constant tuberculous discharge. The open sore at the knee doesn't heal on the application of antiseptics. An incompetent surgeon may amputate the leg for incurable joint disease. A number of such amputations are on record. As the disease advances, localizing symptoms appear in the back, making diagnosis easy."

5

"Amputate his leg! Are such mistakes common?" asked the manufacturer.

"There is no way of knowing the percentage of error in diagnosis in private practice. The probable percentage has been determined, however, for hospital physicians. This was done by comparing their diagnoses with subsequent autopsy findings. It was found in one hospital, for example, that the diagnoses agreed exactly with the autopsy findings in 50 per cent. of the cases. Agreed with sufficient exactness to introduce no error in treatment, in 25 per cent. Twenty-five per cent. of the diagnoses were wrong."

"I surely thought doctors had a higher batting average than that," said the manufacturer.

"The percentage of correct diagnoses is of course often higher than this. With adequate clinical facilities, a conscientious, competent physician can correctly diagnose pulmonary tuberculosis, for example, in at least 97 per cent. of the cases; syphilis and typhoid

fever in fully 94 per cent. There is always, however, an appreciable error even with the most perfect methods."

"You're speaking of experts," said the manufacturer. "How about the common or garden variety of doctor?"

"The average error is unknown. Autopsies are too infrequent in private practice. If every death were followed by an autopsy by an impartial pathologist, incompetent diagnosticians would be driven out of business in a few months.

"The diagnostic errors with certain types of physicians, however, and with certain diagnostic methods, are fairly well known. Data have been collected, for example, of errors by Abrams' electronic method. Numerous patients diagnosed by this method have subsequently come to autopsy. A diagnosis of syphilis with the patient dying of unsuspected cancer of the stomach, a diagnosis of cancer with death from unrecognized heart disease, a diagnosis of tuberculosis with the patient accidentally killed showing normal organs, are typical. If the diagnoses were drawn blindfolded from a hat, the percentage of error would not be greater.

"Probably the most extensive data have been collected regarding the diagnostic error by religio-therapeutists. Diagnosis of cancer by Christian Scientists, for example. Hundreds of their cancer diagnoses have been investigated. In fully 95 per cent. of the cases in which concurrent medical examination was possible, or subsequent autopsy records available, there was no reason to suspect cancer. A neurotic individual with constipation, a woman with a cracked nipple, are typical examples. In only about 3 per cent. of their cases was cancer found. A diagnostic error of 97 per cent."

"Shall we adjourn to our rooms?" asked the manufacturer, as he signed the waiter's slip.

THE HISTORICAL DEVELOPMENT OF SURGICAL ANESTHESIA

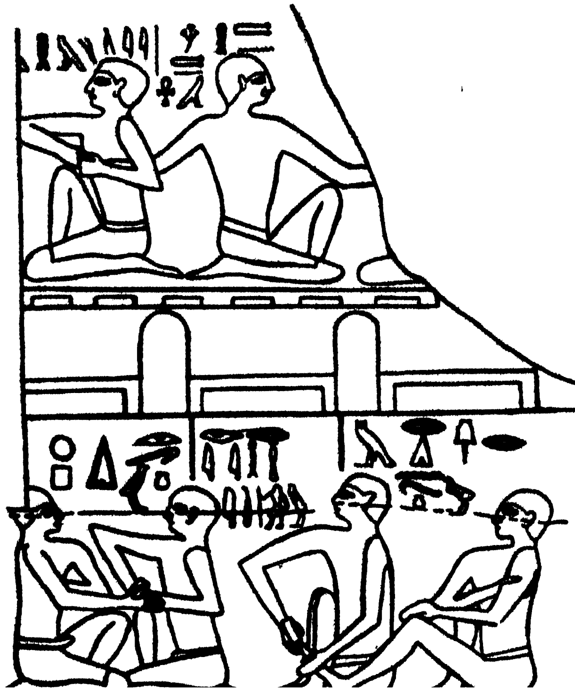
By Professor CHAUNCEY D. LEAKE
UNIVERSITY OF WISCONSIN

THE fundamental aim of medical art and science is, and always has been, the alleviation of human pain and suffering. In no field of medical endeavor has this aim been so satisfactorily achieved as in the development of surgical anesthesia. This is not so remarkable in view of the fact that submission to surgical procedures involves the conscious anticipation of pain and distress far greater than that usually realized in accidents or ordinary sickness. The development of anesthesia from an empirical basis to a firm rational foundation has been one of the greatest achievements of science, and it provides one of the most interesting stories incidental to the growth of knowledge.

Anesthesia may be accomplished in two ways. The bringing about of unconsciousness with general loss of sensation, including of course the sensation of pain, is general anesthesia. On the other hand, the application of an agent to a particular local area of the body, to abolish the sensation of pain in that area, is local anesthesia. It is interesting that local anesthesia was undoubtedly the first type of anesthesia to be used empirically, and it is also the form of anesthesia in which the greater scientific interest lies at the present time.

THE DEVELOPMENT OF LOCAL ANESTHESIA

It is well known that pressure applied to a nerve trunk or artery, particularly along an arm or a leg, will cause the disappearance of sensibility in the area below that on which the pressure is applied. It is this which results in our feet or hands "falling asleep." Many primitive people use pressure in this manner to achieve local anesthesia. At the dawn of civilization this form of anesthesia was practiced, as is shown by the Egyptian carvings illustrating the method. These carvings were discovered on the door-post to a tomb excavated by Loret in the Necropolis of Saqquarah, and they have been dated at 2500 B. C. It must be confessed that only mental suggestion of some sort could make pressure upon an arm effective in producing anesthesia in a leg, in the case of one of the figures, but this particular carving was apparently for the purpose of illustrating how the anesthesia was obtained and not to illustrate an actual operation.



—*From Holmes and Kittermann*

EGYPTIAN CARVINGS

Circa 2500 B. C., illustrating how anesthesia may be produced by means of pressure.

Among the early Assyrians pressure was used on blood vessels to give anesthesia in the customary operation of circumcision. During the Greek and Roman periods, this type of anesthesia apparently was not practiced. It was revived, however, in the early part of the seventeenth century by Valverdi, and again by James Moore in 1784. The latter suggested applying pressure by clamps to the nerves supplying the part to be operated upon, but, as the great surgeon Hunter demonstrated, the plan was impractical.

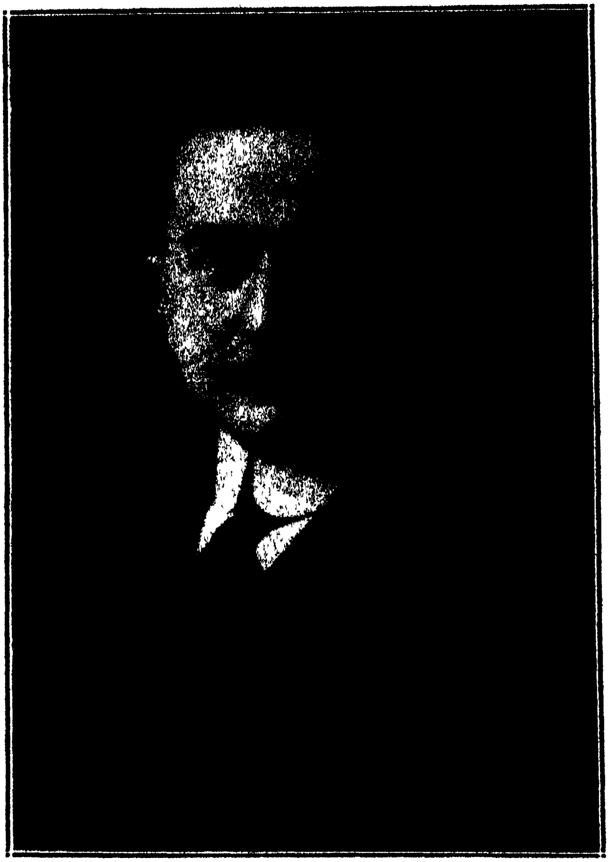
Many other kinds of local anesthesia have been followed until the modern era of cocaine and its derivatives. Dioscorides in the first century A. D. discusses the local application of preparations of mandragora and other atropine-containing plants for the relief of pain. Atropine does somewhat deaden the sensory nerve endings, and various concoctions of plants containing it were used for centuries as local anesthetics. Opium preparations were also applied locally for the same purpose. In 1773, Thomas Percival (1740–1804), who wrote the first "Code of medical ethics," de-

scribed in an essay "On the medicinal uses of fixed air" the properties of carbon dioxide in relieving the pain of raw wounds, when blown against the denuded surfaces. The first carefully conducted experiments with the object of securing local anesthesia were made by Sir Benjamin Ward Richardson (1828–1900), who did so much to place the entire matter of anesthesia upon a scientific basis. He noted the anesthetic effects of cold applied locally and studied the effects of rapid evaporation of volatile liquids in producing cold at a given spot on the skin. In 1867, he introduced what has been termed the Richardson ether spray, for the purpose of producing a satisfactory local anesthesia, and this method was in general use

—*From Moodie*

ARTIST'S RECONSTRUCTION OF PRIMITIVE SURGERY AMONG THE PERUVIAN INCAS

The operator chewed cocoa leaves, permitting the saliva to flow on the wound to induce anesthesia.



—*From a photograph*

DR. CARL KOLLER

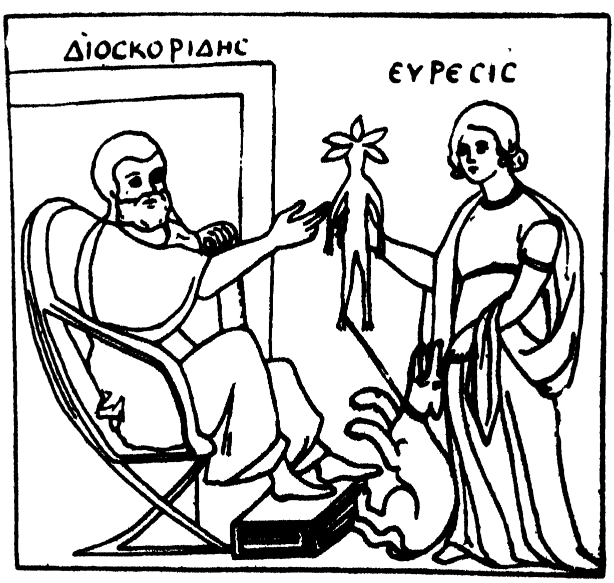
Who demonstrated the local anesthetic properties of cocaine.

for many years. It was later modified by the use of ethyl chloride, a substance which evaporates more quickly than ether, and hence leads to the desired result more effectively.

Local anesthesia was established upon a firm basis with the demonstration of the local anesthetic properties of cocaine. The aboriginal inhabitants of the highlands of South America were acquainted with these properties. Dr. Roy L. Moodie has reconstructed an early surgical operation among the Incas, showing a blanket clad shaman using the cautery to make a cruciform incision in the scalp of a woman suffering from melancholia. The operator chewed a cud of cocoa leaves, the juice from which he could drop upon the wound if the pain became severe.

The steps in the introduction of cocaine as a local anesthetic were many. Alexander Wood, in 1853, introduced the hypodermic syringe, without which the administration of cocaine or its derivatives would be difficult. Albert Niemann, in 1858, isolated cocaine from cocoa leaves, while working in the laboratory of Friedrich Woehler, and both Niemann and Woehler described the numbing effect of the alkaloid upon the tongue, without recognizing the significance of this fact. Cocaine remained a curiosity for many years. In 1880 a British medical commission learnedly reported that the substance had no medical value, being at best merely a poor substitute for caffein. This same year, Von Anrep published a careful pharmacological study of the alkaloid, in which the local anesthetic properties were hinted at, but it remained for Dr. Carl Koller actually to demonstrate its great value.

Due, perhaps, to his own charming modesty, Dr. Koller has not generally received the full credit that he deserves for his demonstration of the local anesthetic properties of cocaine It may be of interest to give such facts in the matter as are available. Carl Koller was born in Schuettenhafen, Bohemia, on December 3, 1857. He graduated from the University of Vienna in 1882 and interned at the Allgemeines Krankenhaus. From 1885 to 1887 he was assistant to Snellen and Donders at Utrecht, Holland, and then came to New York City in May, 1888. He has since continued most suc-



—*From Singer*

THE GODDESS DISCOVERY PRESENTING MANDRAGORA TO DIOSCORIDES

Preparations of this plant were used as anesthetics in Roman and medieval periods.

—*From an engraving*

VALERIUS CORDUS

Who first described the synthesis and properties of ether, about 1540 A. D.

cessfully (a fact to which I may personally testify) in the practice of ophthalmology in New York. Dr Emil Mayer, chairman of the Committee on Local Anesthesia for the American Medical Association, in a report published in the *Journal of the American Medical Association* in 1920, presents Dr. Koller's story of his discovery of the local anesthetic powers of cocaine. Up to the year 1884, the only satisfactory method of local anesthesia was Richardson's ether spray, which was not suitable for eye work Koller tried unsuccessfully to find some way to achieve local anesthesia in eye surgery, and gave up the attempt when his friend, Dr. Sigmund Freud, of psychoanalytic fame, enlisted his aid in studying the physiological effects of cocaine taken internally. Dr. Koller noted the benumbing effect of cocaine on the tongue, as had other workers with the drug since the date of its discovery. It occurred to Koller, however, that here might be the agent for which he was seeking in connection with eye anesthesia. Experiments in Strickler's laboratory in Vienna on animals and normal humans convinced him of the importance of his finding, and he made his first report to the German Ophthal-

mological Society at Heidelberg on September 15, 1884, through the agency of Dr. Brettauer, of Trieste. Later, he published a paper on the subject in the *Wiener Medizinische Wochenschrift*, which was immediately translated into important medical publications abroad, and within a year the new procedure was in use all over the world In fact, so quickly did the importance of the discovery become common knowledge that in 1885 Dr. James L Corning, of New York, had already demonstrated hypodermic and spinal anesthesia with the use of cocaine solutions.

Recent progress in the exact knowledge of local anesthetics, together with the scientific study of their toxicity and therapeutic values, has been greatly facilitated by the appointment of committees for their appraisal in both England and the United States The field has proven a fertile one for the synthesis of chemical relatives of cocaine, and scarcely a year has passed since Koller's discovery without the announcement of a new local anesthetic agent. The most valuable method of inducing local anesthesia, through infiltration, was introduced by C L. Schleich in 1894, while the most satisfactory and least toxic of all the substitutes for cocaine was introduced by the chemist Alfred Einhorn, and the clinician, Dr. H. Braun, in Germany, as novocaine or procaine, in 1905. Braun also introduced the use of epinephrin with local anesthetic agents in order to delay absorption and check bleeding Recently, Dr. Roger

—*From Hollander*

A CARTOON BY GILRAY (1802)

On the experiments of Davy at the Pneumatic Institute.
Davy holds the bellows.

CRAWFORD W. LONG
Who first used ether as an anesthetic on March 30, 1842.

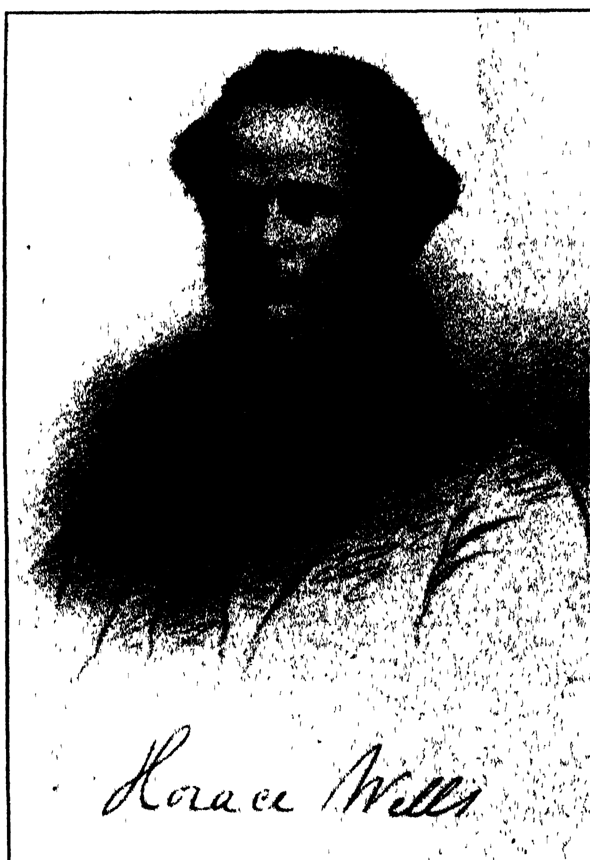
Adams, in this country, has furnished the chief scientific background for the commercial exploitation of "butyn," a substance claimed to have great therapeutic value, especially in eye surgery, but which has been shown to be very toxic. Dr. A S. Loevenhart and Dr. H. L. Schmitz have still more recently suggested "isocaine," a substance chemically related to procaine and to butyn which combines all the advantages of procaine for infiltration work and of cocaine for eye surgery, and which is not as toxic as cocaine or butyn.

The story of the development of local anesthesia, while not as interesting or as lengthy as that of the growth of general anesthesia, is of great importance, because it is quite generally recognized that local anesthesia represents the most satisfactory type of anesthesia, as far as effects upon the patient are concerned, and if the patient's confidence and cooperation can be secured, in the general conduct and expense of the operation. Local anesthesia has been one of the most important factors in the development of modern highly specialized surgery. As our knowledge of the relation between constitution and action of the various local anesthetic agents becomes

more perfect, we may be in a position to synthesize a more ideal local anesthetic, one with high therapeutic efficiency, low toxicity and lasting action.

The Growth of General Anesthesia

General anesthesia seems to have been practiced as anciently as local anesthesia, for references to it occur in the Bible and in Homer Among the most primitive methods of inducing general anesthesia was the stoppage of blood flow to the brain and the consequent cause of fainting, by blocking the carotid arteries by pressure In both Greek and Russian, these arteries are called the "arteries of sleep" It may be that the "temple sleep" induced in the Asclepieia, or health resorts of Ancient Greece and Rome, was some sort of hypnotic anesthesia practiced for the purpose of allevi-



—*From Truman Smith*

Horace Wells

Who first used nitrous oxide as an anesthetic in 1844.

—*From an engraving*
THE FIRST PUBLIC DEMONSTRATION OF SURGICAL ANESTHESIA
Massachusetts General Hospital, Boston, October 16, 1846

ating pain and anxiety. Hypnotism was revived in the eighteenth century for anesthetic purposes, but without success.

There is every evidence that the early Chinese and Egyptians were familiar with the pain-relieving properties of opium and of Indian hemp. Herodotus gives the first reference to inhalation anesthesia when he describes how the Scythians inhaled the fumes from hemp preparations before submitting to surgical operations. A Chinese manuscript has been found which gives the formula for a hemp mixture which when given to patients renders them insensible to pain during operations.

The most important of the ancient anesthetic agents, however, was mandragora, about which a voluminous mythology arose. Just what atropine-containing plant the ancient mandragora was has not been definitely determined, for there are many members of the order Solanaceae (the potato family) from which choice could be made. Moreover, many of these plants contain other potent alkaloids, among them scopolamine and hyoscyamine, which have sleep-producing and analgesic powers.

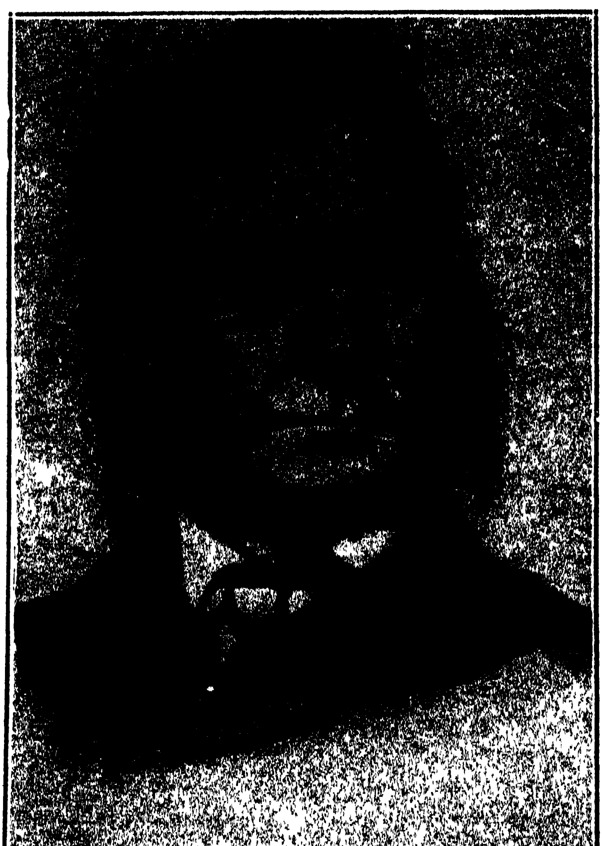
The ancient use of mandragora as an anesthetic agent was well described by Pedacius Dioscorides, a Greek army surgeon in the service of Nero, 54–68 A. D., and this description was later copied by Pliny. Dioscorides is the authoritative source for the materia medica of the ancients, describing, as he did, the medicinal use of some 600 plants. His work was the basis for the therapeutic prac-

tices of physicians until the 16th century. In the 65th chapter of the fourth book of Dioscorides, as well as in other places, direct mention is made of the use of preparations of mandragora to produce insensibility before operations or the use of the cautery:

Aliqui radices in vino ad tertias coquunt, & defaecatum ius feruat, cyathoque uno utuntur, in peruigiliis, & doloribus, & ante sectiones ustionesque, ne sentiantur.

So greatly did the properties of mandragora impress the popular mind that it was endowed with supernatural powers. It was supposed to have been brought to the attention of Dioscorides by the goddess Discovery, who, in accordance with the popular belief, had to sacrifice a dog while gathering the herb.

Variations of this mandragora anesthetic of Dioscorides were used in Europe all through the Middle Ages. By the 13th century



—*From Gwathmey*

CHARLES T. JACKSON

Who tried to patent ether with Morton.

ON THE

PHYSIOLOGICAL EFFECTS

SULPHURIC ETHER,

SUPERIORITY TO CHLOROFORM

BY WILLIAM T G MORTON M D.

BOSTON

[illegible]

—From the original

TITLE-PAGE TO MORTON'S FIRST PUBLICATION ON ETHER

opium preparations began to supplant the earlier atropine concoctions, and for a while the two were used together in the "spongia somnifera" of Hugo de Lucca. Juices of poppy and mandragora, together with various other plants, were boiled with a sponge, which was then dried to be used as needed, by soaking with hot water and applying to the nostrils. In 1589, Giambatista Porta used a similar preparation boiled in a lead vessel with a lid, which could be raised so that the fumes might be inhaled. Owing to the uncertainties of action of these agencies, however, and because of the fatalities incurred, they quickly fell into disuse, and as early as 1543 Ambrose Paré, the great French surgeon, had discarded them to return to pressure applied locally for anesthetic effects.

A large factor in the gradual abandonment of atropine anesthetics was the recognition that opium preparations were far superior in relieving pain and anxiety. The work of Paracelsus (1493–1541) in introducing alcoholic tinctures of opium did much to displace mandragora and belladonna as the anesthetics of choice. Laudanum and similar opium preparations were used to allay pain and distress in surgical operations from the time of Paracelsus to the advent of ether anesthesia in 1846.

It is remarkable that ether itself was discovered about 1540, and there is some evidence that the great Paracelsus himself was acquainted with its anesthetic properties. Ether was first described by Valerius Cordus (1515–1544), who in his brief span of twenty-nine years gave Europe its first Pharmacopeia, inaugurated the systematic study of botany, and was a pioneer in turning from the vain efforts of alchemy to the rational aims of chemistry. The third part of his "De Extractione" contains the earliest known account of the synthesis of *oleum dulci vitrioli* (diethyl oxide) from the distillation of "very biting wine" or alcohol and "sour oil of vitriol" or sulphuric acid The care with which Cordus gives his method and prescribes his standards of purity for his reagents stamps him as a modern in chemical procedures. He found that ether evaporated very rapidly and that it was an excellent solvent for many substances. Being primarily interested in the treatment of disease, he noted that ether promotes a copious flow of saliva and that it relieves hacking coughs and bronchial irritations. These observations are of great interest, because it was probably from the use of ether for these conditions in the early nineteenth century that the anesthetic powers of the substance were finally discovered. Paracelsus, who was a contemporary of Cordus, may have been familiar with the "sweet oil of vitriol," for he refers to an extract of vitriol which had an agreeable taste, put animals to sleep without injury and which had remarkable powers in relieving pain.

By the middle of the 18th century the spirit of critical skepticism was contributing again to a new development of rational medicine With regard to the problem of anesthesia, this was manifested by the critical investigations of Anton Stoerck (1731–1803) of the "Old Vienna School," on the action of stramonium, hyoscyamus and other atropine-containing plants He could find little basis for their use as analgesic agents.

The rise of modern inhalation anesthesia may be traced to the interest in the gaseous elements and their effects on respiration. Joseph Priestley (1733–1804), that interesting clergyman who was forced to flee from England to a mountain home in Pennsylvania, isolated oxygen and discovered nitrous oxide in 1772. The real credit for the discovery of oxygen, however, should be given to Lavoisier (1743–1793) and his wife, because their introduction of quantitative methods in chemistry made them realize its great significance Oxygen and the phenomena of oxidation in the living body are of supreme importance to anesthesia, since they may be concerned with the fundamental explanation of the conditions.

The realization of the significance of oxygen had a singular effect upon medicine. Many theories of disease were formulated on

A

MANUAL OF ETHERIZATION:

CONTAINING DIRECTIONS FOR THE EMPLOYMENT OF

ETHER, CHLOROFORM, AND OTHER ANÆSTHETIC AGENTS,

BY INHALATION,

IN

SURGICAL OPERATIONS,

[illegible]

COMPRISING, ALSO

A BRIEF HISTORY OF THE DISCOVERY OF ANÆSTHESIA.

BY CHAS. T JACKSON, M D., F G. S. F.,

[illegible]

BOSTON.

PUBLISHED FOR THE AUTHOR BY J. B. MANSFIELD,

[illegible] Court Street,

1861.

—*From the original*

TITLE-PAGE TO JACKSON'S BOOK

In which the details of the ether controversy are discussed.

the basis of oxygen want, the real importance of which we are just beginning to appreciate. Among the physicians who felt the spell of oxygen was Thomas Beddoes (1760–1808), of Shropshire, England, who founded in 1798 the Pneumatic Institute at Clifton for the treatment of disease by the inhalation of various gases. The institute failed, but the methods of Beddoes have had some vindication in the modern treatment of tuberculosis by the open-air method and of pneumonia by the administration of oxygen. The most important service rendered by Beddoes to medicine and science was his discovery of Sir Humphry Davy (1778–1829), who served as an assistant at the institute from 1798 to 1801. Davy was a great chemical genius, a poet, a philosopher and an indefatigable worker. His diligent researches on the effects of inhaling nitrous oxide overworked him, and from fatigue and overzealousness in these studies he more than once nearly died. At the institute, Davy was research director, or in the high-sounding phrase of the time, "superintendent of experiments."

Davy's researches on nitrous oxide were most complete and were conducted with much critical skill and ingenuity. He made care-

ful studies of the composition, analysis and properties of the gas, noted its physiological effects on animals, and then by means of an apparatus similar to a modern basal metabolism appliance, he studied its effects on humans. He observed that oxygen lack was of serious consequences, and one of his most famous conclusions was:

> As nitrous oxide in its extensive operation appears capable of destroying physical pain, it may probably be used to advantage during surgical operations in which no great effusion of blood takes place.

Davy attributed the effects of nitrous oxide to internal asphyxiation, since large amounts of carbon dioxide were exhaled after its use. Davy's researches became so well known that they were widely caricatured, the most interesting and famous of which efforts was the celebrated cartoon by Gilray.

The effect of the work of the Pneumatic Institute was to stimulate interest in volatile substances for the treatment of respiratory diseases. By the beginning of the nineteenth century, ether was in widespread general use as such an agent. From this use and from the popular lectures on the action of "laughing gas" or nitrous oxide there developed the custom of having "ether frolics," on which all the young people of a community would get intoxicated with ether while at some backwoods social function. These "ether jags" were very popular in the United States, and from them undoubtedly grew the realization of the anesthetic powers of the substance.

Many earnest experimenters noted the similarity of action between ether and nitrous oxide following inhalation. A note to this effect in 1818 is ascribed, without justifiable evidence, to Faraday. Among the earliest of the real experimental efforts to achieve definite surgical anesthesia were those of Henry Hill Hickman (1800–1829), who was a country practitioner in Shropshire, England. He worked both with carbon dioxide and nitrous oxide, but the ridicule he received at home and the failure of his demonstrations in France so discouraged him that he died in poverty while still a young man.

The story of the development of anesthesia now presents many interesting contrasts, from the calm satisfaction of what was considered modest achievement to the insanity and morbid ill-health occasioned by greed and disappointed egotism. The lives of Crawford W. Long (1815–1878), Horace Wells (1815–1848) and William T. G. Morton (1819–1868), all to be credited more or less with the discovery of real surgical anesthesia, are filled with such human and emotional appeal as to make the story of anesthesia one of the most interesting in the development of science.

—*From an engraving*

WILLIAM T. G. MORTON

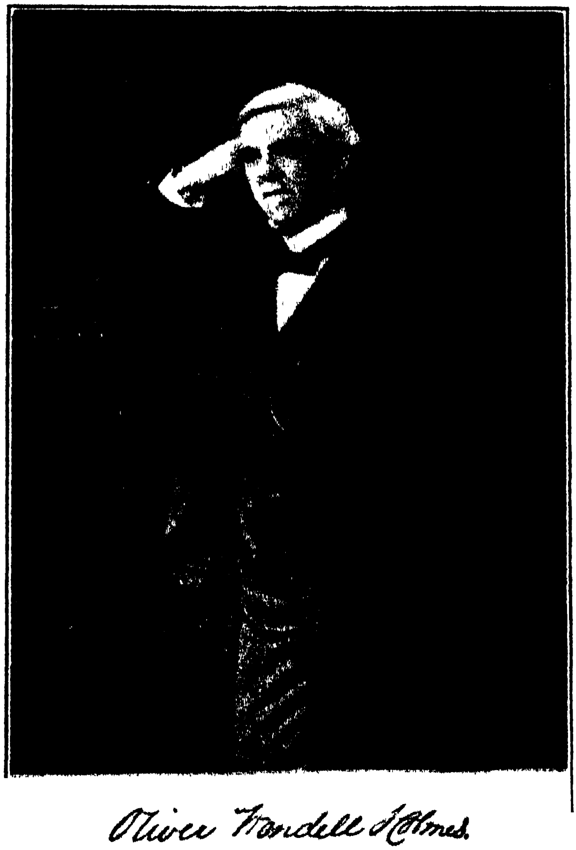
Who demonstrated the anesthetic properties of ether.

Crawford W. Long studied medicine at the University of Pennsylvania, where now a graceful bronze medallion has been erected to his memory. It is stated that he was greatly impressed by the injunction of his professors never to publish any discovery in medicine until it had been fully verified by every means possible, in order to prevent the accumulation of useless medical literature. Long returned to Georgia, where he engaged in rural practice in the village of Jefferson. In the *Transactions* of the Georgia Medical and Surgical Association for June, 1853, Long describes how he first used ether for a surgical operation in 1842. He states that the people of the town had become interested in the exhilarating effects of nitrous oxide and asked him to prepare some for them. This he could not do, because he did not possess the required apparatus.

But he induced them to try ether as a substitute. Joining the "ether frolics" with them, he noted that often he would find bruises upon his body, the pain of which he had not felt while under the influence of the substance, and he noticed that his friends could receive under such conditions blows otherwise very painful. From this he was led to try ether in surgical operations. The first operation of which satisfactory evidence exists was on James Venable for the removal of a tumor on the back of his neck, performed on March 30, 1842, for which the enormous sum of $2.00 was charged. The ether was administered on a towel placed over the patient's nostrils, and the tumor removed without pain. This was repeated several times and mentioned to the physicians of the neighborhood. However, Long made no formal publication of his discovery until later.

Horace Wells was a dentist of Hartford, Connecticut, and was interested in the painless extraction of teeth. Witnessing a demonstration by Gardner Q. Colton on nitrous oxide, Wells noted that a person under its influence felt no pain. He asked Colton to administer the gas to him, and while under its influence had a tooth pulled without any painful sensation whatever. This was on December 11, 1844. In 1845, Wells went to Boston to arrange a demonstration of his discovery before the surgeons of the Massachusetts General Hospital. The inhaler used was apparently removed too soon, the patient gave a cry of pain, and Wells retired in shame under the rebuke of being called an imposter. He continued to give the gas in private, but brooding over his failure drove him insane and he committed suicide in 1848.

One of the witnesses of Wells's failure was William T. G. Morton, a dentist of Boston and a student in the Harvard Medical College. For some time he had been interested in the problem of alleviating pain in surgical operations, and by the failure of Wells was induced to give up the trial of nitrous oxide. He was at the time assisting in the office of Charles T. Jackson, a well-known physician, chemist and geologist of Boston. Jackson suggested that Morton try ether. This Morton did, experimenting first on animals in his own home, to the disgust of his wife, and then upon himself. His experiments convinced him that he had at last found what he desired. Application was made to the surgeons of the Massachusetts General Hospital for the privilege of making a demonstration, whether by Jackson or Morton has not been determined. Jackson, later, at any rate, claims that he sent Morton to give the demonstration as his substitute, since he was busy. The demonstration was arranged for October 16, 1846. Dr. John Collins Warren, internationally recognized as a surgeon of great ability, was to oper-



—*From a photograph*

OLIVER WENDELL HOLMES

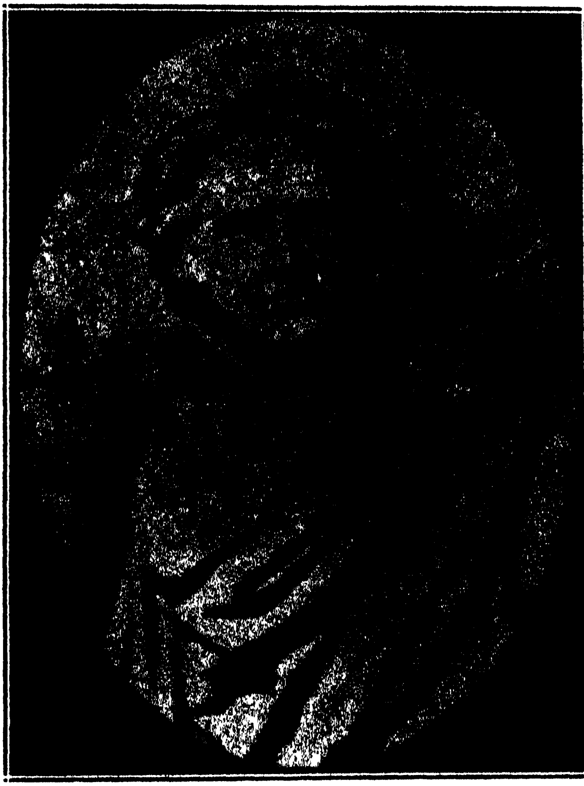
Who suggested the terms "anesthesia," "anesthetic," etc.

ate. Morton did not come on time, and Warren made sarcastic references to his absence. When Morton did arrive in the amphitheater, crowded with his classmates and professors, Warren turned to him with the sharp rebuke, "Well, sir, your patient is ready." Morton had been detained by the completion of a new inhaler he had devised, but adjusting this to the patient, he quietly administered his as yet unknown agent, and turning to Warren replied, "Dr. Warren, *your* patient is ready." Warren operated in tense silence, the patient showing not the least indication of pain or movement. The operation, again, was for the removal of a tumor from the neck. When the operation was finished, Warren turned to the audience and said, "Gentlemen, *this* is no humbug."

The high character and international reputation of the surgeons

of the Massachusetts General Hospital assured the demonstration of complete success so far as publicity throughout the civilized world was concerned. This is an important point to keep in mind Warren and Bigelow, the two most famous of the surgeons, were as much responsible almost as Morton for the rapid spread of the discovery of the relief from pain in surgical operations Bigelow took ether with him to England and there performed the first operation with it on December 19, 1846, in London. Morton, in fact, behaved most reprehensively. He endeavored to keep his secret to himself, and with Jackson attempted to patent his substance on October 27, 1846. The substance was called "letheon," and an elaborate campaign was undertaken to introduce its use in a very commercialized manner in every city in the world. Surgeons were to receive exclusive rights to its use by the payment of huge royalties to the patentees. However, the scheme failed. It was impossible to disguise the fact that the substance was ether, and within a year surgeons all over the world were using it as a routine procedure in operations.

Much has been made over the fact that Long did not publish his discovery made in 1842. Morton did not publish his demonstration, either. It was done for him by the surgeons of the Massachusetts General Hospital. They made all the initial publications in the medical journals of this country (H. J. Bigelow, *Boston Medical and Surgical Journal,* November 18, 1846) and England, and Morton made no attempt to publish anything until 1850, when the chloroform controversy had arisen. Meanwhile, Jackson was sent out to make geological surveys of the shores of Lake Superior, and his interest in ether waned. Morton, however, in 1849, sought to have public recognition of his demonstration made by Congress, with a grant of $100,000. In the acrimonious debate which followed this proposal, the rival claims of Wells and Jackson as the discoverers of surgical anesthesia were brought forward by their friends After five years of bitter wrangling, the friends of Long in Georgia appeared with evidence substantiating his claims It is to Jackson's credit that he made a visit to Long in 1854 and was so thoroughly convinced of Long's priority in the discovery of the anesthetic powers of ether that he withdrew his own claims and made it impossible for any one else except Long to be considered. With characteristic modesty, Long refused public recognition and the controversy ceased. To the shame of science in this country, it was kept up by Jackson and Morton abroad, in the endeavor to secure honors and decorations from foreign governments and societies. In 1861 Jackson published "A Manual of Etherization," in which his story of the demonstration of the anesthetic is given.



—*From Gwathmey*

BUST OF SIR JAMES YOUNG SIMPSON

Who introduced chloroform as an anesthetic agent.

This was a well-written and calm statement, but it is evidence enough that greater modesty would have been more becoming all through to the author. Morton became increasingly agitated in his attempts to push his own claims for financial and honorable reward and died in 1868 in New York City from apoplexy induced by a fit of anger over Jackson's claims, while Long lived in peace and happiness till 1878.

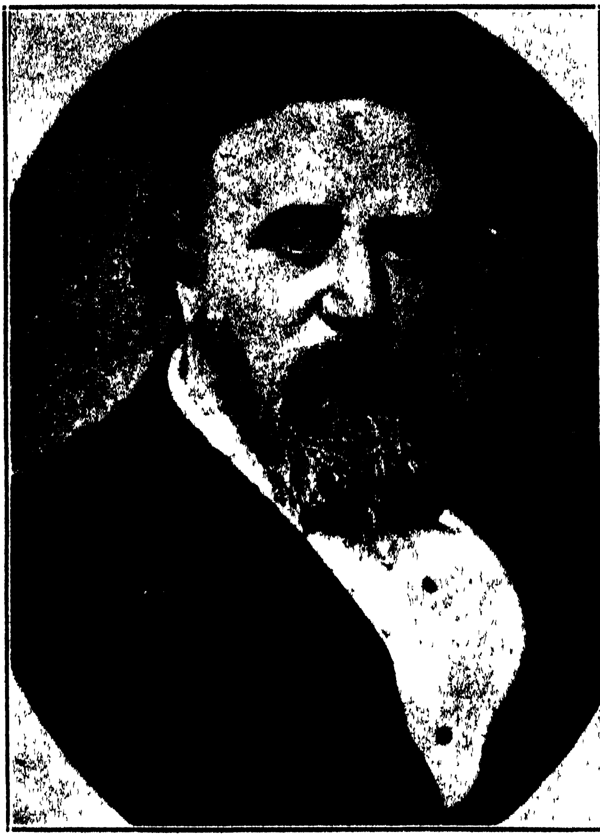
The use of the terms "anesthesia," "anesthetic" and "anesthetist," was due to the suggestions made by the distinguished scholar and poet, Oliver Wendell Holmes, professor of anatomy at Harvard, in a letter to Morton addressed on November 21, 1846. When a monument to the discoverer of ether anesthesia was proposed for Boston Commons, the question arose as to whose name should be inscribed thereon, Long's, Morton's or Jackson's. Holmes suggested, with characteristic wit, that the inscription read "To E(i)ther."

Among the first to use ether in England was J. Y. Simpson (1811–1870). He soon became dissatisfied with its irritating properties and with its odor Upon the advice of Waldie, a chemist of Liverpool, Simpson tried chloroform as an anesthetic in his obstetrical practice. The French physiologist, Flourens (1794–1867), had noted on March 8, 1847, that chloroform had marked anesthetic powers on animals Simpson found it entirely satisfactory, and on November 10, 1847, published his famous pamphlet on a "New anesthetic agent as a substitute for sulphuric ether in surgery and midwifery." As noted by Gwathmey, because of Simpson's writings and efforts in behalf of chloroform, its use spread with great rapidity and it soon almost completely supplanted that of ether.

Simpson's energetic support of chloroform brought on one of the most ridiculous struggles endured in the progress of science. The Scotch theological authorities opposed the use of chloroform for the relief of pain in childbirth on the ground that it was an impious interference with the will of the Lord In early days, women had been burned alive in Scotland for attempting to secure relief from pain in child-bearing, and belief in the guilt of women and in the justice of their suffering was strong in the land. In spite of many well-written arguments on the part of Simpson in justification of his practice, he seemed about to fail, in Scotland, at least, when he won his point by as absurd an argument as can be imagined He pointed out that in the 21st verse of the 2nd chapter of Genesis, the Lord Himself, in the first surgical operation of which we have record, before He took the rib from Adam's side to fashion Eve, caused a deep sleep to fall upon Adam, thus justifying the use of an anesthetic in surgical or obstetrical procedures.

Simpson's work in the introduction of chloroform was rewarded by his elevation to the peerage. It is related that Sir Walter Scott wrote to him on this occasion, suggesting as a coat-of-arms "a wee naked bane" (a small nude baby) with the motto beneath, "Does your mother know you're out?"

The scientific studies which placed the administration of ether and chloroform upon a sound rational basis were made by John Snow (1813–1858), who published in the year of his death his observations and researches. This work was carried on by his pupil, Sir Benjamin Ward Richardson (1828–1900), and by Joseph T. Clover (1825–1882) It was Clover who devised the inhalers which have proven so satisfactory for routine work. Richardson undertook an exhaustive study of all agents which might possibly have an anesthetic value. Among many others, he noted ethylene and methyl ether, both of which have been very recently resurrected for study. Richardson's work has unfortunately been buried in



—*From Scientific American Supplement, 1885*

SIR BENJAMIN WARD RICHARDSON

Who did pioneer scientific research in anesthesia

out-of-the-way publications to which access is difficult. Richardson found ethylene an admirable general anesthetic, its only disadvantage being its gaseous state, which now is no disadvantage. Richardson was a genial scholar and wrote a delightful series of biographies entitled "The Disciples of Aesculapius." One of these essays is a charming appreciation of the life and work of his preceptor, John Snow.

Nitrous oxide, which had been eclipsed by the advent of ether and chloroform, was restored to a substantial position by the discovery of Edmund Andrews, of Chicago, that it should be administered with about 10 per cent. oxygen. Under these circumstances, it was found to be more satisfactory in many conditions than ether or chloroform. The report of Colton, made in 1867, on 20,000 successful cases had previously done much to restore interest in the gas.

A series of sudden and inexplicable deaths occurring under chloroform anesthesia soon made many surgeons very cautious in its use. In 1880, a special committee appointed by the British Medical Association condemned its use on the grounds of results obtained by a most exhaustive experimental study This report was questioned, and a second commission, financed by the Nizam of Hyderabad, filed a report favorable to chloroform. A subsequent committee of the British Medical Association reported in 1891, after studying the records of 26,000 cases of operations under chloroform. It was concluded that no method of administration was free from danger, and the use of the substance, except in certain conditions, was strongly condemned. The most eminent physiologists of England were engaged in these studies, which were of great value in clearing up the mode of death under the action of chloroform. It was conclusively shown that blood pressure and respiration were greatly depressed and that often a reflex stoppage of the heart took place in the first few moments of anesthesia.

The administration of both ether and chloroform was greatly facilitated by the introduction of morphine premedication. This had been suggested by Claude Bernard in 1869 and was first applied by Crombil in Calcutta in 1881. Morphine, the chief alkaloid of opium, had been isolated by Sertuerner in Hamburg in 1806, and had been used to quiet patients and relieve pain before the demonstration of ether anesthesia.

Meanwhile, many sequences and combinations of anesthetic agents had been tried, but for routine operating the drop method of administering ether, almost like that practiced by Long in 1842, came into general vogue Chloroform was found useful in war zones or near an open flame, while skilled anesthetists preferred nitrous oxide and oxygen. In 1915, George W. Crile, the distinguished surgeon of Cleveland, Ohio, began a careful study of the effects of anesthesia on the body, both with respect to the acid-base equilibrium and with respect to the effects upon the nerve cells. From these studies he was led to introduce a combination of local and general anesthesia termed "anoci-association." This did much to stimulate scientific interest in anesthetic agents and their action, and considerable work has recently appeared on the subject. Thanks to the efforts of Dr. D. D. Van Slyke and his coworkers, of New York, and to Dr R L. Stehle and Dr. Wesley Bourne, of Montreal, the mechanism of the production of ether acidosis seems to have been explained. It remains to be seen whether rational measures can now be taken to combat this acidotic effect of ether and chloroform.

The attempt has been made by Dr. Yandell Henderson and his associates at Yale to explain anesthetic shock on the basis of the

rapid removal of carbon-dioxide from the blood during the first few minutes of etherization when respiration is ordinarily greatly stimulated. While this theory has not received much support, it has resulted in the practical use of carbon-dioxide administered with oxygen for the purpose of rapidly removing an anesthetic gas from the body upon the completion of a surgical operation.

It is interesting to note that the greatest advances made in general anesthesia in modern times have originated in the United States and England. The French have been slow to accept either ether or chloroform, and for years used ethyl chloride, a highly toxic substance, following the suggestion of Flourens in 1847. In England and the United States attention to the problems of anesthesia has been maintained by associations of anesthetists, who meet frequently and discuss with enthusiasm the questions confronting them. In the United States these meetings have been promoted largely through the efforts of Dr. F. H. McMechan, of Ohio. In England, the publication of the *British Journal of Anesthesia*, to which Dr Dudley Buxton is contributing valuable and interesting historical papers, will accomplish much in the interests of the specialty.

On March 17, 1923, Dr Arno B Luckhardt and Dr. J. B Carter, of Chicago, published in the *Journal of the American Medical Association* their observations on the anesthetic properties of ethylene. This has been followed by many confirmatory reports, all of which seem to indicate that ethylene-oxygen anesthesia is destined to become of great and increasing importance. This work has aroused great interest in general anesthetic agents, and now reports are appearing from Dr. W. E Brown, of Toronto, and Dr. J. T. Halsey, of New Orleans, on propylene, and from Dr. H. Wieland, in Germany, on acetylene. One of the most significant points emphasized by this recent work is the importance of oxygen in anesthetic conditions. An anesthetic agent is being sought which can be administered with so much oxygen that all deleterious effects incident to oxygen want can be reduced to a minimum. From other factors which enter, however, the ultimate solution of the problem of the ideal anesthetic agent seems to lie in the field of local anesthesia.

APPENDIX

Chronology of the Development of Anesthesia

2500 B.C. Pressure on arteries and nerve trunks used for anesthetic purposes by Egyptians and Assyrians.

1st Century A.D. Dioscorides explicitly mentions use of mandragora locally and generally to remove pain during surgical operations.

13th Century A.D. "Spongia Somnifera."

1530 Paracelsus (1493–1541) introduces laudanum, and opium preparations begin to displace mandragora and belladonna.

1540 Valerius Cordus (1515–1544) discovers ether (oleum dulce vitrioli).
1543 Ambrose Pare (1510–1590) discards spongia somnifera and uses pressure for anesthetic purposes.
1762 Anton Stoerck (1731–1803) critically investigates properties of stramonium, hyoscyamus and aconite
1772 Joseph Priestley (1733–1804) discovers nitrous oxide.
1774 Thomas Percival (1740–1804) notes anesthetic action of carbon dioxide on raw wounds
1790 Antoine-Laurent Lavoisier (1743–1794) explains oxidation.
1799 Humphry Davy (1788–1829) notes anesthetic properties of nitrous oxide.
1805 Ether inhalation quite generally used in phthisis and asthma.
1806 Friedrich Wilhelm Sertuerner isolates morphine and experiments on its physiological action.
1828 Henry H Hickman (1800–1829) experiments on anesthetic action of carbon dioxide and nitrous oxide.
1831 Justus von Liebig (1803–1873) discovers chloroform
1842 Crawford W. Long (1815–1878) uses ether as an anesthetic agent for surgical operations.
1844 Horace Wells (1815 1848) uses nitrous oxide as an anesthetic agent in dental operations
1846 October 16, William T. G. Morton (1819–1868) demonstrates the use of ether as an anesthetic agent at the Massachusetts General Hospital.
1846 October 27, Morton and Charles T. Jackson try to patent letheon
1846 November 18, Henry J Bigelow's paper in *Boston Medical and Surgical Journal*
1847 March 8, Marie-Jean Pierre Flourens (1794–1867) notes anesthetic properties of chloroform and ethyl chloride.
1847 November 4, James Young Simpson (1811–1870) introduces chloroform into obstetrical practice as an anesthetic agent.
1853 Alexander Wood introduces hypodermic syringe.
1858 John Snow (1813–1858) puts administration of ether and chloroform on scientific basis by study of anesthetic concentrations.
1858 Albert Niemann in the laboratory of Friedrich Woehler (1800–1882) isolates cocaine.
1867 B. W. Richardson (1828–1900) introduces ether and ethyl chloride spray in effort to achieve satisfactory local anesthesia
1868 Edward Andrews, of Chicago, puts nitrous oxide on safe anesthetic basis by administering oxygen with it.
1880 Chloroform condemned by committee of British Medical Association.
1881 Alexander Crombil, Calcutta Medical College, applies Claude Bernard's idea (1869) of pre-anesthetic medication with morphine.
1884 Carl Koller (1857–), Vienna ophthalmologist, discovers local anesthetic action of cocaine and applies it to eye surgery.
1885 James L. Corning (1861–) demonstrates hypodermic and spinal anesthesia with cocaine.
1889 Hyderabad Chloroform Commission amplifies B. M. A. committee report.
1893 British Society of Anesthetics formed.
1894 C. L. Schleich introduces infiltration anesthesia with cocaine.
1905 Alfred Einhorn and Braum discover and introduce novocain.
1915 George W. Crile (1864–) develops theory of anoci association.
1922 Discussion of anesthetic shock, and study of effects of anesthesia.
1923 Revival of interest in ethylene and acetylene as anesthetic agents.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

ARTIFICIAL GASOLINE

ONE of the most pressing problems of the present time is: What are we going to do when the oil runs out? If that question is not answered within the next ten or twenty years, the pressure on parking space will automatically be relieved through the growing scarcity of automobiles, aviation will remain a rarity and the small shop will tend to extinction through loss of its handy engine.

Already the question has become acute in countries less oily than ours. In England, Germany and France chemists are hard at work trying to invent ways of making something to match the natural petroleum that is still being so recklessly wasted with us. The three countries are pursuing different ways toward the solution of their common problem, and all have recently reported some measure of success in getting gasoline from coal.

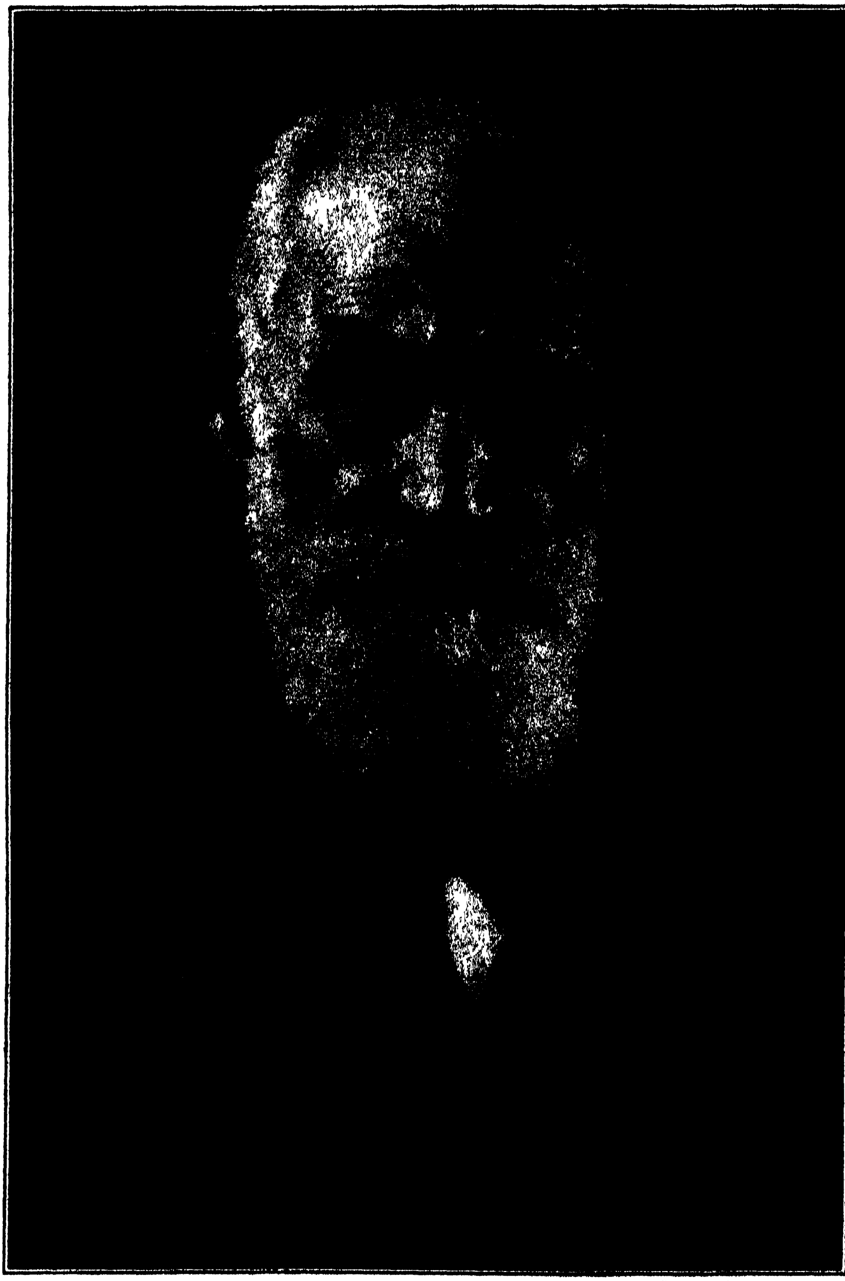
The British Department of Scientific and Industrial Research is experimenting in low temperature carbonization and has worked out a process that gives a gaseous fuel for local use, a liquid fuel suitable for motors and a solid smokeless fuel, which they call "coalite," for household and industrial purposes.

In Germany the Bergius process of treating powdered coal with hydrogen under high temperature and pressure is said to be capable of converting low-grade lignite into a synthetic petroleum equal to the natural.

In France, a Rumanian chemist, Georges Oliver, in collaboration with a French mining engineer, Charles Andry-Bourgeois, has invented a process claimed to be capable of converting coal, wood or any kind of carbonaceous material into gasoline of higher heating value than that obtained from petroleum. This is accomplished by the aid of certain catalysts which have the power of effecting the desired combination of carbon with hydrogen at high temperatures. Exactly what these catalysts consist of is not revealed in the account of the process given in the October issue of *La Science et La Vie*, but they are stated to be made of certain metallic powders spread upon infusorial earth, pumice, clay, charcoal and other porous bases.

The first stage of the process is similar to the familiar method of making coke and illuminating gas. The coal or lignite is mixed with from five to twenty-five per cent. of lime, soda or alumina and heated in tight retorts. The distillate of tar, ammonia and light oils is condensed and utilized. The coke remaining in the retort is converted into water-gas by the well-known method of passing steam over it while red hot. Water-gas is a mixture of hydrogen and carbon monoxide, both excellent combustibles and both employed in later parts of the process.

The gaseous output of the coke oven consists of free hydrogen, methane and more complex compounds of hydrogen and carbon. It is essential for the next step that there should be an excess of hydrogen. If the mixed gas contains less than fifteen or twenty per cent. of hydrogen by weight more must be added. This additional hydrogen may be obtained from



—*From "Nature"*

IVAN PETROVIC PAWLOW

The distinguished Russian physiologist who recently celebrated his seventy-fifth birthday.

the water-gas or, if necessary, by decomposing water by the electric current.

The second stage of the process consists in passing these gases through an electrical furnace heated to 3,000 degrees centigrade. This transforms the methane into acetylene and changes the other hydrocarbons into forms more active and ready for combination.

The gaseous mixture so obtained is next conducted under pressure through tubes containing the catalyzing agents. The temperature at the beginning of this, the third stage of the process, is about 150 degrees centigrade at first, but rises to 400 degrees at the end. Contact of the gases with these finely divided metals somehow causes the smaller molecules to hook up together and form larger molecules, and the colorless gas that entered the tube comes out as a colored oil, which, like the distillate of natural petroleum, looks red by transmitted light and green by reflected light. It contains about 75 per cent. of very light gasoline.

In the fourth and final stage this colored oil is again passed over metallic catalyzers with an excess of hydrogen at a temperature of 180 degrees. The finished product is a light limpid colorless liquid having a very agreeable odor. It consists largely of what the chemist calls the "hydrogenated compounds of the benzene series," such as cyclohexane. In composition it consists of about 86 per cent. of carbon, 13.5 per cent. of hydrogen, with very little oxygen and less sulfur.

The process seems pretty complicated, but according to figures of M. Olivier gasoline can be manufactured from the French lignites at a cost of twelve cents a gallon, which is less than a third the present price of gasoline in France. The initial plant constructed at Asnieres is expected to turn out a thousand tons a day. Twenty-five per cent. of the carbon in the original coal comes out in the form of gasoline. The rest is mostly employed in heating the gas and apparatus and running the engines.

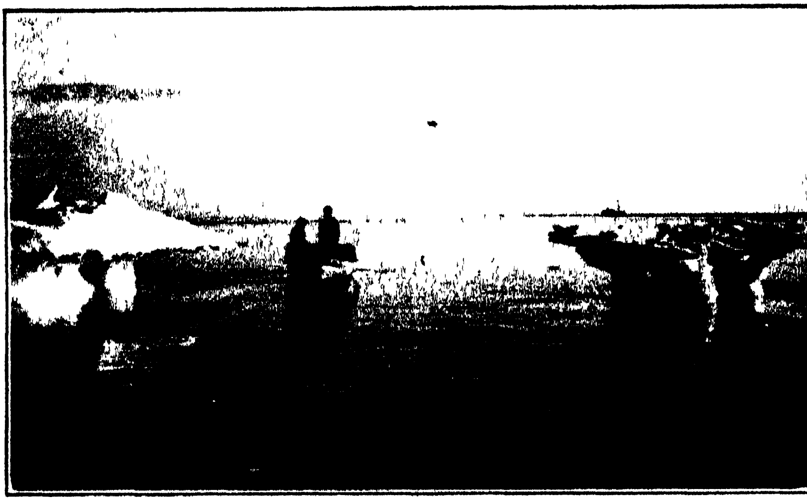
STARTING A NEW DISEASE

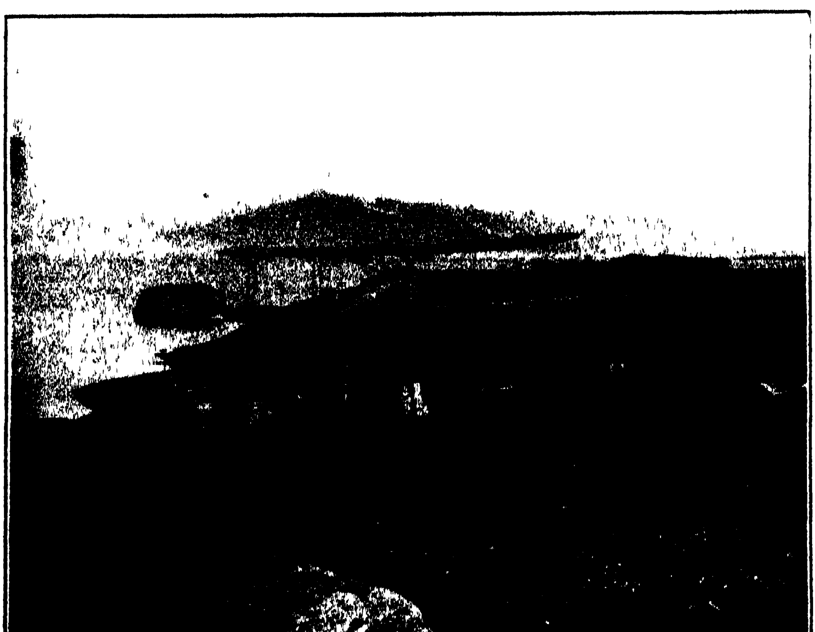
We would suppose that there were diseases enough in the world so that no one would rejoice over a new one. Yet few of the thousand papers read before the recent session of the American Association for the Advancement of Science aroused more enthusiasm than that in which Dr. James Johnson, of the University of Wisconsin, told how he had started a novel malady in tobacco and tomato plants by inoculating them with the juice of healthy potato vines. The diseased plants may in turn infect other plants of the same or other sort and so on indefinitely, the virulence of the virus increasing with each stage.

It seems that what is one plant's food is another plant's poison and that the wholesome sap of the harmless necessary tuber may induce a fatal infection of the weed whose poisonous nature we were warned against in childhood.

The disease is first manifested as a faint mottling of the larger leaves of the young plants, but after passing through two or more generations of tobacco it becomes intensified and causes dead spots or blotches. It belongs therefore to the class called "mosaic diseases," not in reference to the Mosaic law but because they are commonly recognizable by scattered white patches that make the leaf look like a cross-word puzzle, only there isn't any answer to it, or at least the biologists have not yet found the answer.

They do not even know whether the virus of the mosaic diseases belongs to them or to the chemists. It seems to stand somewhere between the two





THE OXFORD UNIVERSITY ARCTIC EXPEDITION

On and near the Polar island of North Eastland, the survey as has been concluded from the air and about its coasts with two ships and motor boat. Wireless is extensively used in these operations, the seaplane and ships being in touch, while sledges equipped with radio installations are also used.

sciences, between the animate and inanimate kingdoms, if there is such an intermediate state. There are dozens of different mosaic diseases known in the plant world, as definite and distinguishable by habit, host and symptoms as are smallpox and measles. The active agency, whatever it may be, can multiply indefinitely and infect in succession any number of other plants in the vicinity to which the virus may be carried by sucking insects, as mosquitoes or fleas carry malaria or plague. From this we should naturally infer that a mosaic disease is due to a minute living organism, a microbe.

But this appears impossible because of their extreme minuteness. They can not be discerned with the most powerful microscope. They pass through the pores of a collodion membrane or a filter of unglazed porcelain, such as is supposed to take out every solid and suspended particle and pass only pure water and the salts dissolved in it. This would make them out so small that it would take some forty or fifty thousand of them, side by side, to measure up to a millimeter, or some three thousand of them to be as thick as this sheet of paper.

"But," says the chemist, "such a minute mass would be a mere structureless sphere. It is smaller than a molecule of protoplasm and could not possibly contain all the machinery essential for a living creature and its descendants. Besides, molecules don't breed."

"But don't they?" retorts the biologist. At least Dr. Johnson suggests as a possible solution of the mosaic problem that the ultimate molecule or particle of the virus may be capable of reproducing itself when transplanted into the favorable environment of the living cells of the host plant. Another suggestion is that the virus injected into the cell may stimulate this to production of some substance, injurious to itself, which in turn is capable of setting up a similar stimulus in other cells. There is a third possibility, that is, that the apparently healthy potato was a carrier to the virus of tobacco plant as certain people, without harm to themselves, will harbor and distribute the typhoid germ. But this last theory is highly improbable, for Dr. Johnson used extracts from fifty different potato vines, the best to be found on the farm, and got infections of tobacco from them in every case. He tried inoculating tobacco with forty species of plants other than potato but failed to get any symptoms of disease.

So it seems that there must be something in the cell sap of the potato that starts a self-perpetuating disturbance of some sort in plants of the same family. But the susceptibility appears to be confined to the Solanums, so nobody need fear the potato unless he belongs to the family. Nor do any of the mosaic diseases attack human beings. I mention this lest the reader should get a prejudice against the potato and leave it out of his dietary for fear of getting a spotted skin.

The Solanum family has suffered from a bad reputation, perhaps because it comprises such unwholesome plants as belladonna, henbane and jimson weed. Potato, tomato and tobacco when they were introduced into Europe a few hundred years ago met with furious opposition. They were all three accused of being injurious to both health and morals. But the potato and tomato are now welcomed to the most exclusive tables and the tobacco is welcomed at all tables except the most exclusive.

DR HENRY S. WASHINGTON

of the Carnegie Institution of Washington, who is making a series of chemical analyses of the lavas of the volcanoes of the Hawaiian Islands.

THE AFRICAN MANLIKE APE SKULL

By Professor Raymond A. Dart, of Witwatersrand University, South Africa

The skeletal remains of Australopithecus Africanus consist of two fragments. One is an endocranial brain cast (the form of the interior of the cranium) and this is complete and whole. The other is the face of the skull which was found completely imbedded in the limestone of an old cavern. This ancient cave was completely filled with bedded sand infiltrated with lime.

The site of the discovery is near the locality of Taungs, Kalahari, Bechuanaland and the cave is in the Kaap Plateau composed of dolomitic rocks

The skull is dolichocephalic (long and narrow and somewhat oblong in shape). The face is leptoprosopic (relatively long and narrow).

The remains are those of a juvenile subject with the first permanent molars erupted. The brain has a size just slightly larger than that of an adult chimpanzee. The sulcus lunatus (the lunar fissure, one of the convolutions of the brain) shows a position approaching the same feature in the human being. The brain shows marked temporo-parieto-occipital expansion (enlargement of the posterior or back two thirds of the cerebrum). There is an absence of the pre-rolandic and post-rolandic flattening of the skull (That is, the muscles of the jaw at the stage of evolution shown by

DR. C C. KIESS

Of the United States Bureau of Standards, with the apparatus he used on board the dirigible *Los Angeles* to photograph the eclipse of the sun on January 24.

the skull had decreased in size due to lack of hard usage so as to allow the brain in the region of the temples to bulge out. This is a human-like characteristic.)

The ridges above the eye orbits of the skull are absent (unlike those in apes). The eye orbits are rounded. The nasal or nose bones terminate above the line connecting the lower margins of the eye orbits. (This is human-like.) The upper dental arch is parabolic in shape (this type of setting for the teeth is more nearly human than that of the apes). The canine teeth are small and their diastema (the space between the canine and front teeth) is three millimeters. There is no diastema or space in front of the canine teeth of the lower jaw. This lower jaw resembles in its front portion the famous Heidelberg jaw.

Another point of importance showing the jaw's close approach to human characteristics is the lack of a simian shelf, a ledge on the interior of the lower jaw present in the apes. The canines of the jaws are small and lie in line with the slightly crowded vertical incisors or front teeth.

The foramen magnum (hole through which the spinal cord enters the brain) is placed well forward. (In the monkeys this is well to the rear of the skull and its location in the newly found skull indicates that the creature to whom it belonged may have walked upright.)

The specimens are diagnosed as those of a manlike or anthropoid ape, and classified as a new family, the Homosimiidae.

That the skull of the anthropoid ape child found by Professor Dart in Africa is an important link in the ancestry of man is the opinion of Dr. Aleš Hrdlička, anthropologist of the Smithsonian Institution, after he had read and studied the article sent by Professor Dart to *Science Service*.

The remains of this four-year-old child, just beginning to cut its first permanent teeth, will probably take their place beside Pithecanthropus, Piltdown man and the other famous relics of man's evolution and antiquity. Buried as they were deep in limestone, Dr. Hrdlička believes it probable that they date from Tertiary times, a time more ancient than any in which human remains have heretofore been found. In this case they have been preserved for hundreds of thousands of years.

The fact that the skull was so young when its owner met death is a disadvantage from the standpoint of anthropological study, for the skull of a young ape has more human characteristics than the skull of an adult ape

Yet there seems to be little doubt but that there has been discovered on the reputed "dark" continent a most important step in the evolutionary history of man who arose from the same stock as the present apes Australopithecus Africanus is probably more remote in human ancestry than Pithecanthropus, the ape man of Java, up to now considered the oldest manlike creature known to science.

Australopithecus was not an ape-man like Pithecanthropus, but a man-ape. He was a creature who emerged just before the dawn of man. He is one of those beings popularly known as a "missing link," intermediate forms having both human and ape-like characteristics.

Australopithecus may be related to America through two lines, that of man and monkey. The descendants of Australopithecus through evolutionary processes may have become modern man. His ancestors evolving in a different direction may also have given rise to the kind of monkeys that now inhabits South America.

Dr Hrdlička believes that the new African man-ape is more closely related to the old African stem of the American monkey than to the type of monkey now living in the old world. It is generally conceded that the American type of monkey came from Africa in Tertiary times when there was a land bridge between Africa and South America. In characteristics, Australopithecus resembles the American type of monkey more closely than the African.

THE SCIENTIFIC MONTHLY

APRIL, 1925

CAN LIFE EXIST ON MARS?

By Dr. W. W. COBLENTZ

BUREAU OF STANDARDS

WHAT of Mars? Can the astronomers find out? Thus ran the headlines of the daily press this past summer. Many were the questions asked: Has Mars an atmosphere; what are the white polar caps; is the surface sufficiently warmed to support life? The popular idea seemed to prevail that Mars was a beautiful orange-colored ball rolling toward us until August 22, when it would suddenly disappear from view. Hence, the importance of trying to learn some of its secrets on this bewitching night.

On the other hand, the astronomer saw no need of being excited on this date. A shortening of the distance between the earth and Mars by a few hundred thousand miles was of less importance to him than good seeing over a prolonged interval of time, so that he could trace the seasonal changes in the markings of the surface.

During the months of June to September it was my good fortune to have twenty-four clear nights of good observing on Mars; and here is my reply to some of these questions. The information was obtained by means of a delicate thermocouple radiometer of two kinds of wires, almost as fine as a spider's thread, the junctures of which were flattened into little disks no larger than the period which ends this sentence. These thermocouples were mounted in the eyepiece of a reflecting telescope, and the little round disks of metal, called "receivers," were exposed to the dark and the bright spots on Mars and on small craters of the moon. The heat-rays coming from these spots warmed the little metal disks, giving an indication of the temperature of the surface. As already stated, these receivers were so small that eight separate settings could be made across the image of the disk of Mars, which was only 2 mm (one sixteenth of an inch) in diameter.

The first measurements on stars were made at the Lick Observatory, Mount Hamilton, California, in 1914, and continued at the

Lowell Observatory, Flagstaff, Arizona, in 1921, 1922 and again in 1924, where with the faithful assistance of Professor C. O. Lampland, I have been able to pursue these planetary investigations. We have developed a system of teamwork, which for speed and accuracy in the most trying moments (which are numerous) compares favorably with that of an inanimate, automatic recording device. The scientific world owes a debt of gratitude to this little observatory for its courageous efforts in extending the boundaries of knowledge into the unknown. Looking back over the search of more than eleven years for facilities to try out these thermocouples and its happy culmination in the study of this wonderful planet at this time, it would seem as though all had been in accordance with some prearranged plan. Almost fifty years must elapse before such a favorable opportunity will again occur.

The Martian day is about half an hour longer than our own. Mars has seasons similar to our own, but of double the length; and as summer progressed on the southern hemisphere the thermocouples showed a gradual warming up of the surface, just as we notice a gradual warming of the earth from April to July. But there is a great difference in temperature of the bright and the dark areas on Mars. Even on the equator the noonday temperature of the bright areas, which are probably dry deserts, is but little above freezing. The adjacent dark areas are somewhat warmer, having temperatures of 40° to 60° F. This is just the reverse of terrestrial temperature conditions. While this difference in temperature might arise solely from a difference in absorptivity of the surface, it appears that the dark areas may be at a lower level than the bright areas, which would prevent winds and retain the heat.

Since everybody was interested in Mars on August 22, I shall give some of our measurements. On this date there was no phase on Mars, that is to say, the whole surface facing us was brightly illuminated, and these thermocouples showed that the noonday temperature of the bright regions on the equator was about 5° C. (40° F.), while the adjacent dark regions were perhaps up to 15° C. (60° F). At the same time the temperature of the east limb or sunrise edge was — 45° C. (— 50° F.) and the sunset edge was 0° C. The temperature of the illuminated polar regions was down to — 70° C. (— 90° F.), which is not much different from our Arctic regions The temperature of the night side probably drops below — 80° C. These extreme daily temperature variations are no doubt owing to a rare atmosphere; but they also seem to indicate that this atmosphere is more extensive than was heretofore supposed to be present on Mars.

It will no doubt be realized that these temperature values were established under great difficulties, and that it was quite an accomplishment to obtain any reasonably accurate measurements at all on the poles. Hence, the numerical values may not fit the calculated values for different parts of the surface as accurately as we might desire. That is to say, the calculated temperature gradient from the equator to the poles may not be as great as observed; but this will be merely another proof of the presence of an appreciable atmosphere on Mars. However, as already stated, temperatures of — 60° to — 70° C. occur in our polar regions. Hence, it should not be surprising to find equally low temperatures in the Martian polar regions.

What about life on Mars? That depends upon our viewpoint; whether we think of tropical vegetation or the mosses and lichens which thrive under our Arctic snows and in this latitude during the mild days of January to March, but which shrivel up in summer. These measurements show that for a few hours at noonday on the equator of Mars the surface temperature is not unlike that of New York or Philadelphia on some bright day in March and April. But consider the exceedingly cold nights. The great daily variation in temperature of perhaps 100° C. indicates that the density of the atmosphere is very low. No doubt water exists on Mars, but it is not present in sufficient quantity to form large lakes. What little there is boils at about 45° C. (115° F.) and with a midday temperature of half that value, it appears that during the noon hour evaporation of water proceeds rapidly, while during the cold nights much of the water vapor is removed from the atmosphere.

Hence, with noonday temperatures of only 5° C. to 15° C. (40° to 60° F.) even on the hottest spots on the equator, and with exceedingly low temperatures at night, it seems evident that any vegetable or animal life that may exist on Mars must be adapted to withstand these great extremes in temperature and humidity.

Such adaptation seems possible in low forms of living matter, for example, the brilliantly colored lichens which one sees growing on the old lava flows of Arizona, bordering on the Colorado Desert. It is of course well known that the horned toad is accustomed to drought and has about three months of activity during the summer. However, it was a surprise to find that even our common garden toad can adapt himself to dry conditions. I saw one above ground near the observatory on the only really wet night we had in July. But with practically no rain from April to October he had a quiet time of it underground this past summer; and he will have a still quieter time during the coming long winter. Martian life would be equally inactive for the greater part of the year.

It seems evident that while life on Mars appears to be possible, it must be of a kind that can withstand prolonged drought and intense cold. Moreover, with temperatures changing in six hours from freezing half-way up to the boiling point of water, on Mars, evidently the reactions must be rapid. With much of the surface at frigid temperatures, it is reasonable to assume that if vegetable life similar to ours can exist on Mars it must be like the mosses and lichens which can thrive in cool weather. Similarly, animal life must be troglodytic, able to burrow deep and hibernate, or able to withstand the intense cold in a benumbed state, as do, for example, the torpid grasshoppers, wasps and ants one finds on warm days in winter.

Apparently life on the equatorial region of Mars is a continuous process of thawing out and limbering up in the forenoon and a reversal of the process in the afternoon. On the other hand, in the polar regions where the Martian day is from 8 to 12 terrestrial months in length the temperature rise may not be as high as on the equator. But, during the long summer day in the polar regions the temperature variations will not be so extreme and living matter, if present, will not be subjected to such short periodic changes in activity as occur on the equator. From this it appears that in the polar regions of Mars the cycle of reproduction, development and death of the living cell would not be subjected to the hazards that occur on the equator. Similarly, the quiescent period during the prolonged winter would be free from interruptions.

It seems unnecessary to speculate further on this question. The object of this paper is to present our data in a truthful manner. For it is the first time in history that physical measurements have been made which give an indication that the temperature of the surface of Mars rises above the freezing point of water. Prior to our measurements of 1922, and especially those (including of course the Mt. Wilson measurements) of 1924, the general opinion prevailed that the temperature of Mars is far below freezing. On the basis of these new measurements speculation is already rife concerning life on Mars, and the popular press already contains grotesque portrayals of life on this planet. The foregoing is written merely to show some of the limitations of the environment if life exists on Mars.

OBSERVATIONS ON ANIMAL COLORATION

By AUSTIN H. CLARK

UNITED STATES NATIONAL MUSEUM

In any landscape anywhere the most conspicuously colored living objects are first of all the butterflies and next those birds that live in tree or bush tops or habitually frequent the ends of branches.

Among the most brilliant of the butterflies almost invariably the females are much duller than the males. They are also less proficient on the wing and fly less, and for a shorter period, each day. On the under side all butterflies of either sex are dull and cryptically colored, except for certain Riodinidae which rest with their wings outspread.

Among the brilliant birds that live in tree tops or frequent the ends of branches the females are much duller than the males, on the back at least, in nearly all those types that build an open nest. But if they nest in holes, like kingfishers, motmots, rollers, jacamars, wrens, titmice, woodpeckers, toucans or parrots, or in covered nests, like honey creepers, or if they lay their eggs in the nests of other birds, the females are quite or almost quite as brightly colored as the males. In the Lesser Antilles most of the humming-birds and all the orioles are equally brilliant in both sexes, in this respect differing widely from their mainland relatives.

Any hypothesis by which animal coloration is explained must take these facts into consideration, in connection with the correlated fact that most ground-living vertebrates, except for certain lizards that live in open country, and most insects, except for various flower or rock-frequenting flies, bees, wasps and beetles, are dull or cryptically colored.

It is idle to assume that to us male orioles, tanagers, humming-birds, goldfinches, etc., are less conspicuous than their somber-colored mates or that the gorgeous males of Morphos are cryptically colored, except when resting.

There seems to be a simple explanation of the coloring of the butterflies, the flower-frequenting insects and the tree-top birds, as well as that of other types which live exposed in open places, especially in semi-desert regions.

The enemies of these are chiefly birds, insectivorous and predaceous types, that hunt by day. As is well known, birds have the most extraordinary vision. Their olfactory sense is poor; their sense of touch is also poor; and though some nocturnal types and a

few others hear with a keenness most remarkable, generally speaking the birds that fly by day are not so quick at catching sounds as are most mammals. Birds, therefore, depend for their existence, for finding food and for protection from their enemies largely on sight alone.

A bird's eye is a wonderfully perfect mechanism. It differs chiefly from a mammal's eye in being built about a lens of shorter focus. The image projected by the lens of a bird's eye therefore lies all in one plane or nearly so, resulting in the equal definition of all the objects in the field of vision. This is quite necessary for an insectivorous bird catching its prey upon the wing or for a predaceous bird. Distance means little to them, detection of their victims everything.

To a predaceous or an insectivorous bird a landscape would consist of a clear-cut patchwork of myriads of fragments of all sorts of colors and of sizes. Each stick and stone and leaf would stand out sharply, no matter how distant it might be.

Against a background of this kind those objects would be least conspicuous which were most boldly colored in the sharpest contrasts, dark and light, more or less regardless of what the colors were. For instance, a brown butterfly broadly marked with red and yellow would appear merely like a quiver, not like a butterfly, for at any given time one or other of its colors would grade into a similar color in the patchwork underneath it. I have noticed this in watching Heliconii. Movement of the victim plays the most important part, of course, in its detection. But detection is one thing, capture quite another. Practically all creatures with vividly contrasting colors laid on in a bold pattern, butterflies or other insects, birds and other vertebrates, are restless and nervous in their habits, thus increasing the effectiveness of their coloration.

In the relatively long focus mammal eye and the corresponding lizard eye sharp vision is only possible in a single plane, which is continually shifting back and forth. Beyond this plane the landscape becomes blurred and tends to be reduced to the average color of all its various elements.

Thus the creature least conspicuous to a mammal or a lizard would be one most nearly like the *average color* of the background against which it would ordinarily be seen, and not adorned with sharply contrasting colors, dark and light, matching the *details* of that background, as in the case of birds.

The difference in the sight of birds compared with that of mammals and of reptiles would easily explain the brilliant colors of most butterflies when on the wing contrasted with their cryptic colors when at rest; the brilliant colors of many flower, rock and fence fre-

quenting insects; the bright colors of most male tree-top birds and the dull colors of their mates, unless they lay in holes or covered nests or live in regions like the Lesser Antilles, where there are (or were till introduced by man) no predaceous mammals nor bird-eating reptiles.

It would also easily explain certain anomalies of coloration, such as the conspicuousness of skunks, which have no mammalian enemies but are frequently the prey of great horned owls, and the brilliant coloration of the truly arboreal squirrels of the tropics and of certain tree-top monkeys.

Probably also it explains the assumption by the males of many of our migratory birds in winter of the female plumage. With us the males of tanagers, orioles and similar birds live in the tree tops, continuously exposed to the attacks of hawks but immune from the attacks of mammals and of reptiles, while the females are more or less immobilized at or near the nest or young and are less often seen. In the winter both sexes are the same in habits and are more or less retiring like the females in the north, bringing them within the range of mammals and of reptiles. Some of our birds, like the little redstart, have the same habits in their winter quarters as in their summer home, and in these the same plumage is retained throughout the year.

Practically all male birds when singing in the daytime choose a situation where they are immune from attack by mammals, mostly in tree tops, on rocks or hovering in the air; but evening songsters sing from the interior of trees or thickets where they are protected from the attacks of owls. Some birds, like one of the West Indian mockingbirds (*Mimus gilvus*), sing from the tops of bushes in the daytime, but from the interior at night.

It has never seemed quite plausible to me that sexual selection could have a bearing on the coloration of the birds and butterflies. My belief has always been that the differences existing, which are sometimes very great, would eventually be interpreted in terms of differences in the environment of the sexes.

Recently I obtained what seemed to me to be a clue to what these differences are. Naturally near-sighted, a landscape never appears sharp to me; everything is softened by a lack of definition, and against this blurry background butterflies and birds stand out with great distinctness. I have some glasses which correct this perfectly. With them the background is resolved into an infinity of sharp patches of all shapes and sizes and of widely different colors. I notice that against this background it is very difficult to follow the courses of butterflies, especially the more conspicuous ones, like red or white admirals. Those easily seen, like the whites and yel-

lows and the satyrines, are very rapid or irregular fliers, practically impossible for any bird to catch, or such types as *Terias lisa* and *T. nicippe*, which are protected by their resemblance to more powerful pierines.

A curious feature connected with animal coloration is that in all groups the most splendid iridescence occurs in the American tropics, along with the greatest development and splendor of both groups of fireflies and the extraordinary development of the prehensile tail in many groups of mammals, in contrast to the gliding flight of many mammals and reptiles in the oriental tropics.

Mr. Thayer has ably shown that iridescence is a most effective type of concealing coloration. I have noticed this myself in watching Morphos, the most brilliant of all butterflies.

In the South American forests animal life for the most part is restricted to the tree tops, which typically form almost an unbroken canopy. The maximum development of tree-top coloring should therefore be expected. Furthermore, in traveling through a more or less continuous leafy canopy gliding flight is of no advantage, as it is in the more open forests of the east; so far as possible the animals must endeavor to remain always within the protection of the canopy, and to this end the prehensile tail is a great asset. Underneath this canopy the conditions favorable to the existence of the fireflies and unfavorable for the existence of their enemies are developed to the maximum degree.

For the most part brilliant iridescence is confined to tropical types, both in birds and butterflies. If northern or southern types are iridescent the iridescent areas are mostly red, as in rufous and ruby-throated humming-birds and copper butterflies. But in the tropics iridescent birds and butterflies are not confined to the hot lowlands. There are many in high mountain regions where the temperature is low.

In South America I was surprised to see how difficult it is to follow the great blue Morphos in their flight; the change from blue to purple and to green was most confusing. But in Massachusetts I was equally surprised to find that dead Morphos were always great blue butterflies, while the little coppers are as confusing in their flight as are the Morphos in the tropics.

The only explanation that occurs to me is that in the tropics, where the sun is directly overhead and the iridescent butterflies fly only in the middle of the day, the direct rays give the maximum effect to iridescent colors, while in the high latitudes the greater diffraction of the light destroys the value of such iridescence, especially in the shorter wave lengths.

COOPERATION AMONG SCIENTIFIC MEN

By Dr. WALTER P. TAYLOR

UNITED STATES DEPARTMENT OF AGRICULTURE

I. Science is a benefactor of humanity, but, unfortunately, so far, the world does not "stir itself to make it possible for its benefactors to live and work." This makes necessary organized voluntary cooperation among intellectual workers.

Science has done much to better the lot of mankind. It has helped to eliminate disease, superstition and ignorance. Its beneficent services underlie and maintain the complicated structure of modern civilized society. It has remained for science, through innumerable contributions to production, transportation and communication, to make of the world a unit, such that democracy and world brotherhood, formerly the dreams of far-sighted men of prophetic insight, have for the first time in history become actual possibilities. Scientific men and intellectual workers generally, to whom these advances are due, should be recognized as among the most valued servants of society, and, as a matter of course, provided with the economic essentials to good work. Unfortunately, however, the public has no clear appreciation of the fundamentally important rôle played by the intellectual worker, and, as a consequence, makes very little effort properly to support his work.

(1) The intellectual worker should realize that he, himself, as well as the public, has a definite responsibility for the conditions under which he works.

The advance of the intellectual worker has been slow and painful. No longer a slave, as in the days of imperial Rome, he has at least attained the status of a quasi-independent clerk to property or the state, all too often, it must be confessed, hired and fired at the will of an autocratic individual or governing board according to the commodity law of supply and demand. Even under these hampering conditions he has played a fundamentally important part in building the modern world.

It is clear that civilization can not go forward, can not even be maintained, without the contribution of the intellectual worker; it is equally obvious that the intellectual worker can not do his best work unless he himself has won economic and intellectual freedom. The responsibility for providing proper surroundings of economic and intellectual freedom for the brain worker rests on at least two groups, namely, the public and the intellectual worker himself, and I am inclined to think that the heavier responsibility rests upon the

latter. For the worker knows, or ought to know, the conditions he must have for effective operations, while the public for the most part does not.

No longer should the intellectual worker stand and wait for the public to recognize the value of his work and to provide the essentials for it. He has played this waiting game in this country for lo, these many years, with the result that science has not progressed as it should, and education has been far from satisfactory. An English scientist recently made the very pertinent comment (*Nature*, December 22, 1923, p. 912) that the proportion of Americans eminent in science is disappointingly small when the resources of the country are taken into account, and we are bound to admit that his comment has some foundation. The public, unfortunately, is occupied with many other things than science; the stock market, property rights, the heavyweight championship, the national defense, the income tax, the all-engrossing daily round of duties. Few people even glimpse the significance of science in civilization. For this it seems certain that the scientist is partly, perhaps largely, responsible. Science has made civilization possible. Is it not time the scientific worker wrote his declaration of independence from hampering economic conditions? Does it accord with the essential worth of his work that he should be compelled to play the courtier to the politician or to the Napoleon of industry? Is it well for him to continue to be a dependent, subsisting as best he may on the uncertain bounty of a philanthropic capitalism? (MacDonald, "The Intellectual Worker and his Work," 1924, p. 319). It seems clear that the intellectual worker ought to stand on his own feet, tell the public what is needed, and inspire such pressure of popular opinion as is necessary to get it. This implies the possession on the part of the scientist of ability to enlist the attention of the public, and to insure some sort of equality of bargaining power between himself and his employer. There are three roads to power; the road of the genius, whose power is a gift from the gods; the road of the plutocrat, whose power is derived from the money he has made or taken; and the road of the cooperator, whose power comes from the agreement of many minds on certain fundamental issues. The road to be taken by the intellectual worker is plain. On the average he certainly is not a genius; nor is he a money maker; but he has demonstrated that when he desires to do so he can become a cooperator.

The problems involved in the insuring of proper working conditions among scientific men are of far more than individual significance. The intellectual worker should be the first to appreciate the fact that he is bound up in a web with all his colleagues. On the professional and scientific sides this has long been recognized,

and it is no less true in the social and economic spheres. Whenever the status of any group of intellectual workers, whether of pay or tenure or freedom to study or teach, is impaired, the status of all is so much less secure; and, correspondingly, wherever the condition of any group of intellectual workers is improved, the situation is just so much better for all the rest. It seems clear that these principles apply to intellectual and scientific-technical workers quite generally, irrespective of the accident of their employment by university, museum, academy, private scientific foundation, or state or federal government. They might well be made the basis for increased sympathy, loyalty, and helpfulness, in short, for a vastly augmented cooperation, among these workers. It appears that only through some such proper cooperation can the scientific worker maintain his own respect and make his best contribution to world progress.

(2) One essential to effective cooperation among scientific men is the definite abandonment of ultra-individualism, and its replacement by group loyalty, sympathy and mutual helpfulness.

The work of the scientist has always been on a lofty ethical basis, though founded almost altogether on an individualistic philosophy. The ethics of cooperation are higher and considerably more difficult of successful attainment than the ethics of individualism, but they promise far more for the future.

Close attention to one's specialty with little thought of the other fellow is the line of least resistance for the intellectual worker. Ultra-individualism, like ultra-nationalism, once the "flame upon the altar," is now likely to be "a devastating scourge."

On the other hand, compulsory cooperation, effected through a disciplinary organization of scientific work and workers such as Elihu Root appeared to have in mind a few years ago in connection with the organization of the National Research Council, could not possibly be effective or successful in the long run. Such pseudo-cooperation would, in my opinion, work greater havoc than a rampant individualism. In order to be helpful cooperation must come from within the ranks, and must be a very liberal affair, allowing for the widest differences of opinion and interpretation, and acting rather as a stimulus than as a damper on individual initiative.

In commenting on certain policies of farmers' cooperatives, a writer in Wallace's *Farmer* (February 8, 1924) calls attention to the necessity for remembering that these practices are means rather than ends. "The end we are striving for," he says, "and that cooperative organization seems most likely to bring about, is the creation of a rural civilization that will offer the greatest opportunities for the freest development of the human spirit." Similarly,

what intellectual workers are striving for, and what voluntary organized cooperation seems most likely to bring about, is the creation of an educational atmosphere that will offer the greatest opportunities for the freest development of the human spirit.

When I refer to group loyalty, I do not necessarily limit the concept to one particular group; but it ought to be realized that the pervasiveness and purity of group loyalty, sympathy and mutual aid among intellectual workers may be taken as an earnest of the possibility of their expanding these great conceptions to embrace all humanity.

(3) Definite organization for the economic as well as the scientific advancement of intellectual workers will naturally follow the development among them of the cooperative spirit.

Cattell (THE SCIENTIFIC MONTHLY, Vol. 14, 1922, p. 568) has called attention to the fact that scarcely any group has been so backward in democratic organization as men of science; and there is no other in which conditions make the right kind of organization more necessary. As already suggested, the securing of the minimum rights and guarantees for effective service of the public will require some acquisition of power. Whether or not it is widely realized or intended, it is true, nevertheless, that the intellectual workers at present are often the defenseless victims of organized power of other groups, political, industrial or religious. As Ames (*Science*, October 25, 1918, p. 410) has said, the scientific men of America have suffered greatly at the hands of the people. Handicaps of the sort implied are inevitably reflected in less effective research and education. After all, the public is really the chief party at interest when the adequate maintenance of scientific work is under discussion; for on the maintenance of such work the public welfare absolutely depends.

(4) The practicability and desirability of the organized cooperation of intellectual workers is demonstrated by actual accomplishments in many places, more especially in certain European countries and in England.

The organization of intellectual workers has made notable progress in recent years, particularly in Europe. In France, some three or four years ago, M. Henri de Jouvenel, one of the French delegates to the League of Nations, succeeded in establishing the Confédération des Travailleurs Intellectuels, which now comprises no less than 83 societies with 180,000 members, and which represents practically every intellectual occupation in France (MacDonald, *op. cit.*, p. 290). Similar associations have been formed in eight other countries (*British Medical Journal*, quoted in *Science*, May 18, 1923). A meeting of representatives of these associations was

recently held at the Sorbonne, with the countenance of the French government and under the honorary presidency of M. Leon Bourgeois, one of the most universally respected of French statesmen. It was attended by observers from nine other countries. After a brief discussion it was decided to found a Confédération Internationale des Travailleurs Intellectuels.

Ultimately, it is to be hoped that the organization of scientific workers in this country would affiliate with other intellectual workers in such societies as the American Medical Association, the American Institute of Chemists, the American Association of Engineers, and the numerous other organizations of brain workers, to form an American Federation of Intellectual Workers. American scientific men would then be ready to take their place, whenever they wished to do so, in the international body.

(5) Warlike economic policies will not ordinarily appeal to the intellectual worker.

While it is perfectly proper that any institution dominated by arrogant autocrats, who sacrifice academic freedom to some form of partisan expediency (religious, political or industrial) should be isolated by force of an aroused and indignant professional public opinion, such an association of intellectual workers as that proposed would seldom find it necessary to resort to economic violence, especially if it was generously and loyally supported by large numbers of scientific men. The organized power of this group, like that of the physician and the engineer, would for the most part be exerted in investigating the economic problems of the scientific worker, in educating the scientist and the public to pertinent facts and needs, in peaceful cooperative effort to influence opinion or legislation in the way it should go, and in widespread and pitiless publicity. These tactics, coupled with a refusal on the part of eligible scientists to accept positions from which the prior occupant was known to have been unfairly dismissed, would undoubtedly be effective in most cases. Probably no group in society recognizes more clearly than the intellectual workers the superior effectiveness in the long run of peaceful and evolutionary economic policies as compared with more violent measures.

II. Organized cooperation will make science more efficient.

(1) Experience in the worlds of business, labor and agriculture demonstrates the economic advantages of organized cooperation.

There are few who would deny that organizations of business men, manual workers and farmers have been economically advantageous to the groups represented. It is increasingly evident, also, that proper organization affords a medium for the maintenance of higher standards of service to society on the part of these groups, respectively.

(2) Poor pay, insecure tenure and dependency, which tend to lower efficiency, would be gradually eliminated by organized cooperation.

An early result of any organized cooperation worth the name would be the securing for intellectual workers of improved status of compensation and tenure. As a writer in *Science Progress* stated some years ago (quoted in *Science*, May 4, 1917, p. 433) perhaps the worst form of scientific snobbery is the pretense that the man of science is above cash in any form. As in other fields so in science " . . . the proper and honest procedure is to pay for the work done . . . ." As Dawson has said (*Science*, June 7, 1918, p. 550), the undowered muse is a proposition not only personally inconvenient, but also incompatible with the highest efficiency. Is it fair, in a democracy, that research on the subject of one's choice should be a luxury attainable only by those who have independent incomes, or who are willing to give up the prospects of a family? (Giesy, *Science*, January 11, 1924, p. 46).

The pay-scale for intellectual workers would not need to be commensurate with services rendered. As Cattell has said (THE SCIENTIFIC MONTHLY, Vol. 14, 1922, p. 569), full payment would be three fourths of the wealth produced annually by industrial nations. Underpayment may help to insure purity of motive and be beneficial if it is not carried too far. But is it not reasonable to insist that the compensation of scientists be put on a basis such that each worker can do his chosen work under reasonably effective conditions? Certainly Preston Slosson's suggested schedule of pay for professors (*Science*, August 24, 1923, pp. 140–142) does not provide for over-compensation of the competent.

The intellectual worker is, of course, supposed to take out shortcomings in his salary in honor and dignity. But, as MacDonald well says (*op. cit.*, pp. 255–256), "The supposititious dignity which popularly attaches to certain intellectual occupations has long since ceased to be anything more than a cloak for discrimination and exploitation, an excuse for systematic underpayment, and a consequent wholesale lowering of living standards. It can never be undignified to assert and enforce one's just claims to recognition and fair treatment."

Of first concern to the maintenance of adequate professional standards among intellectual workers is the question of tenure. The right to his job of the experienced scientific-technical worker who has demonstrated his capacity must of necessity be secure if he is to do his best work. Dismissal should only be possible on grounds of proved immorality or gross incompetency, and only after the careful consideration of each case by a jury composed not only of

administrative officers, but of professional colleagues, some of whom should be members of other institutions than the one directly concerned. Advance notice of the intended action, with charges preferred in writing, and opportunity to make adequate presentation of his side of the case, should be the irreducible minimum of protection for any professional worker. It is coming to be more widely recognized that any other course of action is bound to result in impaired morale among the intellectual workers not only in the institution affected but elsewhere, and to be followed sooner or later by a train of untoward and unfortunate circumstances involving loss, on the part of the workers, of academic freedom, peace of mind, respect for the offending administrative officials and self-respect. The ultimate effects of such action are likely to prove even more disastrous to the administrative officials involved. The greatest losses of all, however, are borne by the public, through the inevitable decline in standards and impairment of efficiency of its scientific servants. There is probably no current question affecting the status of intellectual workers more significant than this one of tenure, and I venture to say it will never be satisfactorily answered until the scientific-technical group succeeds in establishing some far more effective scheme of organized cooperation than any that has been achieved heretofore.

In this connection professional ethics should be understood to require a careful investigation on the part of every candidate for a position of the circumstances surrounding the departure of his predecessor; and the acceptance of a position by a candidate, when his predecessor is known to have been unfairly dismissed, should be recognized as constituting a serious breach of professional honor.

(3) Organized cooperation would promote that freedom of teaching and research which is essential to good work.

As President Hopkins, of Dartmouth, said recently, "The minute that education becomes something besides sincere and open-minded search for truth, it has become a pernicious and demoralizing influence rather than an aid to society and an improver of civilization." It is the veriest truism that the maintenance of civil and academic liberty is essential to the accomplishment of effective research and education. Surely it needs not to be said that academic freedom is only the freedom to try to see the world as it is and to try to tell others what is observed and what conclusions seem to be indicated. It is obvious that only through the obtaining and maintenance of freedom of this sort can we hope to maintain our civilization or to win a higher one. The trials and tribulations of the workers in economics, politics, sociology, philosophy, Bible study and biology in some institutions should be recognized as full

of concern to all intellectual workers. Cattell's assertion in his commencement address to the graduating class of the University of Arizona, 1924, that he knows of no socialists who are members of departments of political science in any American university is not without significance. A proper cooperation between intellectual workers implies determined opposition to all forces whatsoever that threaten academic freedom, and unvarying support to individuals or groups who help maintain it. Not only moral, but also financial encouragement, where necessary, should be given, by the rest of us, to any of our colleagues who happen to be on the firing line in this age-long fight.

In suggesting cooperation in organization as a protection for professional prestige, there is no necessary idea of friction with administrative officials. Only those administrative officers whose policies ought to be opposed would ever run afoul of such an organization; and such an association would be a continuous source of power and support to those progressive administrators who recognize the mutuality of obligation between an institution and its personnel, and who stand sturdily for the advancement of intellectual workers and their work.

(4) Scientific standards would be raised.

The doctors and lawyers very properly give close attention to standards of admission to their ranks, thus insuring protection to themselves and the public from the inefficient and the poorly prepared. Similar attention to standards on the part of other intellectual workers may be relied on to bring about great improvements Certainly standards should be high enough to insure that only those would be admitted to the profession who could give adequate service. This would prevent an over-supply of cheap intellectual labor, with the concomitant lamentable competition for underpaid positions. Fewer workers in all these lines, better trained and better paid, would be best not only for the workers and their families but for the public as well.

III. More effective scientific and intellectual service is greatly needed by mankind.

(1) To promote the health, welfare and happiness of the people.

Howard (*Science*, December 30, 1921, pp. 650–651) and others have called attention to the fact that the firing line in the most serious struggle for existence is that between man and insects and still lower creatures. Authorities of the Biological Survey of the United States Department of Agriculture estimate that the western farmer pays tribute of $300,000,000 annually to rodent pests alone. The problems of coping with animal and plant pests, including disease producing organisms, are vital matters to our species.

Of equal importance is the group of questions associated with the maintenance for all of a fair standard of living. These include the problems of (1) Population, (2) Conservation (of soil, mineral resources, forests and valuable plants, beneficial wild life), (3) Maintenance of scientific research and invention (especially in respect to food, shelter, health, power, transportation and communication), and (4) Sociology and economics (including war, education, distribution of wealth and commodities, poverty, crime). It is obvious that the solution of problems in all these groups will fall, in large part, on intellectual workers. Take the war against the insects, for example. Howard's conclusion is that in order to accomplish the very necessary task of bringing the great group of insects under control the services will be demanded of thousands of skilled biologists. Recurring epidemics of foot-and-mouth disease in this country emphasize the fact that in serious emergencies of this kind the people of state and nation can only turn to the scientific-technical group for help. The trouble is that our information is insufficient because of inadequate research work; and there are not enough well-trained scientists, the paradox being that the public takes very poor care of those now in the field. Cattell once suggested (The Scientific Monthly, Vol 14, 1922, p. 570) that in a nation whose maximum military establishment was placed at 100,000 the number of scientists engaged in research should be made a minimum of 100,000. Efficient defenders of mankind from his insidious insect, rodent and microbe enemies can be provided by the universities But the public must be educated to see the necessity for something more than starvation wages and uncertain tenure for these defenders. It will not do for educational institutions to go on turning out biologists and others if the end result is to be merely the swelling of the ranks of cheap intellectual labor. The scientific-technical workers must cooperate to make the public see this.

(2) To secure a more equitable distribution of the results of scientific discoveries.

No economic system which permits the colossal rewards of modern industry which the scientist has made possible to go almost exclusively to the few while the many lack the necessaries of life can ever receive the seal of his approval. The ignorance and greed so obvious in the organization of modern society threaten the integrity not only of scientific work, but of civilization itself. Often they are linked with special privilege, seized and held by the powerful and the unscrupulous. The intellectual workers as a cooperating group should be in the forefront of efforts to eliminate them.

(3) To prevent war.

The use of the products of science in war is a monstrous perversion of the purpose of science. Jordan ("Footnotes to Evolution," 1913, p. 374) has well said that the ultimate end of science is the regulation of human conduct. Seeing true means thinking right. Right thinking means right action. To bring about right action is the end of science. Greater precision of thought and action makes higher civilization possible. The statement that " . . . science, mental endowments and education are no specifics against a wicked heart" (Withrow, *Science*, June 15, 1917, p 596) is unfortunately too true, and it is a reproach to every intellectual worker.

Of recent years and especially since the world war, there has been an increasing protest against the use of science to develop improved methods of killing one's neighbors. A writer in *Nature* (December 22, 1923, pp. 889–891) recently quoted from Galsworthy as follows: "We have made by our science a monster which will devour us yet, unless by exchanging international thought we can create a general opinion against the new powers of destruction so strong and so unanimous that no nation will care to face the force which underlies it." Mr. Galsworthy, it seems, believes that more pains should be taken to apply the methods of science to human problems, to face the facts honestly and fearlessly, and to base just conclusions upon them.

In this whole matter the scientific-technical man has a prime responsibility, and it is gratifying to note that he is recognizing it. Witness the following significant incident involving an eminent British university professor. Some years ago, just after the war, the British War Office invited a number of scientists to become members of a committee to develop to the fullest extent "both the offensive and defensive aspects of chemical warfare." One of those invited, Dr. Frederick Soddy, professor of chemistry at Oxford, refused indignantly, as he " . . . felt that universities and scientific men stood for something higher than had yet found expression and representation in governments, particularly in their international relations" (*The New Republic*, November 24, 1920, p. 307). Professor Leonard Barstow, F.R.S., in his presidential address before the National Union of Scientific Workers in 1921, also spoke in opposition to the suggestion of the War Office that university professors should be given charge of secret laboratories working on the preparation of life-destroying chemicals. "None of us," he said, "can regard without horror the possibility of the destruction of our wives and children by murderous inventions, and we feel that science may be so used by the governments of the world as to effectively wipe out mankind. Aeroplanes carrying lethal gases can not be regarded as signs of progress, whereas aeroplanes which can

safely carry mails and merchandise or facilitate the rapid provision of succor in dire calamities are things to be desired'' (MacDonald, *op. cit.*, pp. 226–227).

In commenting on the position of the scientist in the war against war, a recent writer (Glaser, *The World To-morrow*, February, 1924, p. 46) has suggested that the scientist might well formulate his intent to refuse in times of peace to work on bombs, poison gas and projectiles in something akin to the ancient oath of Hippocrates, which even to-day adds dignity to the medical profession; and he goes on to suggest that if the scientist were to ally himself with others of like mind in his profession and the medical and scientific group as a whole were to link its fortunes with some international group of labor large enough to strike effectively and at the same time keep from starvation and out of jail, there is little doubt that science could prevent the prostitutions and desecrations which to-day make it as much an instrument of harm as good. As we recall some of the results of the last war, five million war widows, nine million war orphans, ten million refugees, twenty-six million lives lost, three hundred thirty-seven billions of dollars spent (Page, ''War, Its Causes, Consequences, and Cure,'' special edition, 1923), we can begin to realize that we are fighting for our lives with the war system. On the issue of this struggle will depend not only the possibility of maintaining a fair standard of living, but the very existence of civilization. It is science which makes war so damnably efficient; why should not scientists exert the might of their cooperative influence against war, and in behalf of a great constructive peace program in its place?

(4) To strengthen democracy.

Science having made democracy something more than a dream of the prophets, scientific men and intellectual workers have a prime responsibility to help make it workable and effective. The results of science must be taken to the people and the distribution of these results must be put on a fair basis. All science, both pure and applied, should be for use by mankind. As J. C. Merriam once wrote (*Science*, November 19, 1920, p. 476), ''Research should lead to construction and is not complete unless the results are available for general use.'' In theory most of us agree with this principle, but in practice we fall short of realizing it. Over-absorption in a specialty is not only one of the principal reasons why the individual scientist is exploited on every hand, but it also lessens his contacts with public problems for the proper solution of which his work is essential. As Branner has well said (*Science*, May 4, 1917, p. 418), ''Our presidents, governors, judges, mayors and others in public life need the services of men of science.'' Geddes (*California*

Alumni Monthly, 1922) has called attention to the fact that while every country has had a great number of lawyers in its government, one must seek far to find the country in which the best medical minds, the best engineering minds, the best scientific minds, are taking part in the national government, directly as responsible legislators and cabinet officers. The matter of health, he says, is purely a question of good government. The same may almost be said of questions of economic adequacy and of such problems as war, poverty and crime. "We will never," says Geddes, "get really satisfactory governing bodies until we have got the best thought in each of the great scientific lines of thought represented effectively in them. We must arouse the scientific and well-instructed men out of their absorption in teaching, in the work of a profession, and interest them in government." These remarks of Geddes imply a very lofty and difficult conception of the duty of the intellectual worker, and demand from him a willingness to cooperate with the community which I fear few of us possess at present. It is perfectly certain, however, that in addition to our very proper present-day ideals of whole-hearted devotion to our specialties we must assume a new ideal of professional and community cooperation. I suspect our hardest task will be, not in awakening the public to the need for more liberal support of scientific work, but in educating ourselves to work and strive together, to be cooperators instead of competitors.

Greatly needed just now is a new declaration of confidence in democracy. There seems to be a temporary widespread dissatisfaction with the way democracy has worked out, not only in the state, but in the church, in industry, and even in education. This has paved the way for the reascendancy of dictators, in many provinces of life and in many countries. Millikan (*Science*, October 19, 1923, p. 294) asserts that the supreme question which the present generation faces is "Can we make democracy work?" Is it not desirable that the scientific investigator assume the responsibility for making democracy work in his own sphere; for insisting on a more democratic basis in his institution, and for associating democratically with his fellows in a consideration of common problems? Why should we not learn to take "a more rational, a more objective, a more scientific attitude" toward the conditions under which intellectual work is done, as they affect the kind, quality and amount of the product?

Democracy is admittedly difficult, with its program of cooperation, brotherhood and mutual aid, and with its utterly impractical tendency to regard the individual as an end in himself. But do we wish to reinaugurate an era of autocracy, with its intent to deliver

the world to the strong, the ruthless and the egotistic, the kaisers in government, industry and education? The answer is plain as soon as we state the question.

The alternative to autocracy is organized democratic cooperation. We shall look forward to the time when, through this kind of working together, the intellectual workers shall have attained to the full stature of manhood, and when, self-respecting and respected, they shall have won that economic liberty which must precede intellectual liberty, and shall have demonstrated to the satisfaction of all that "science and its applications should be a chief concern of a democratic nation that would preserve its democracy and advance the freedom and the welfare of its people" (Cattell, THE SCIENTIFIC MONTHLY, Vol. 14, 1922, p. 577).

ON THE TRAIL OF THE VANISHING SPRUCE

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THE romantic story of the "lost tribe" has invariably caught our fancy, in whatever form it has appeared. There is a wistful appeal in the picture of an isolated community, preserving in some forgotten corner of the world the manners and customs of a far-distant homeland. The original lost tribes of Israel or the fabled lost "Atlantis," the realm of Prester John, the imagined but never discovered remnant of the Aztecs in Peru, all these and many others have beguiled us, down to the survival of seventeenth-century England that is found to-day in the mountains of Kentucky and Arkansas. All unknown to many, we have in this country another lost tribe, a vanishing race, whose romantic history antedates even that of Israel or the lost Atlantis, and which has remained through the centuries, isolated in an alien land, and yet clinging persistently to the characteristics of its own kind hundreds of miles and thousands of years away. The "lost tribe" in this instance is not, however, a kind of men, but a species of tree, or rather two related species, red spruce and Fraser fir, direct descendants of the Canadian spruce and balsam.

When northern America awoke from its long sleep under the great blanket of ice, animals found new lairs and plants new habitats. Marked changes in climate had been wrought by the southward movement of the glaciers. There had been a slow southward procession of boreal climatic conditions, which irresistibly set to migrating all species which were able to migrate. Not animals alone, but vegetation as well, had spread southward in advance of the great glacier. Even trees had migrated with the rest, the northern species finding new sites as the warmth-loving southern species were frost-killed and driven forth.

In this manner the red spruce came from its home in the north and, well in advance of the last reach of the ice sheet, established itself in the region now covered by the Central Atlantic states. The migration was not confined to spruce alone, for birch, beech, maple and other northern species traveled in the same caravan. All doubtless became well established in this part of the country, until

AMES FORESTERS
"hiking over the hills and far away" to the native haunts of the red spruce.

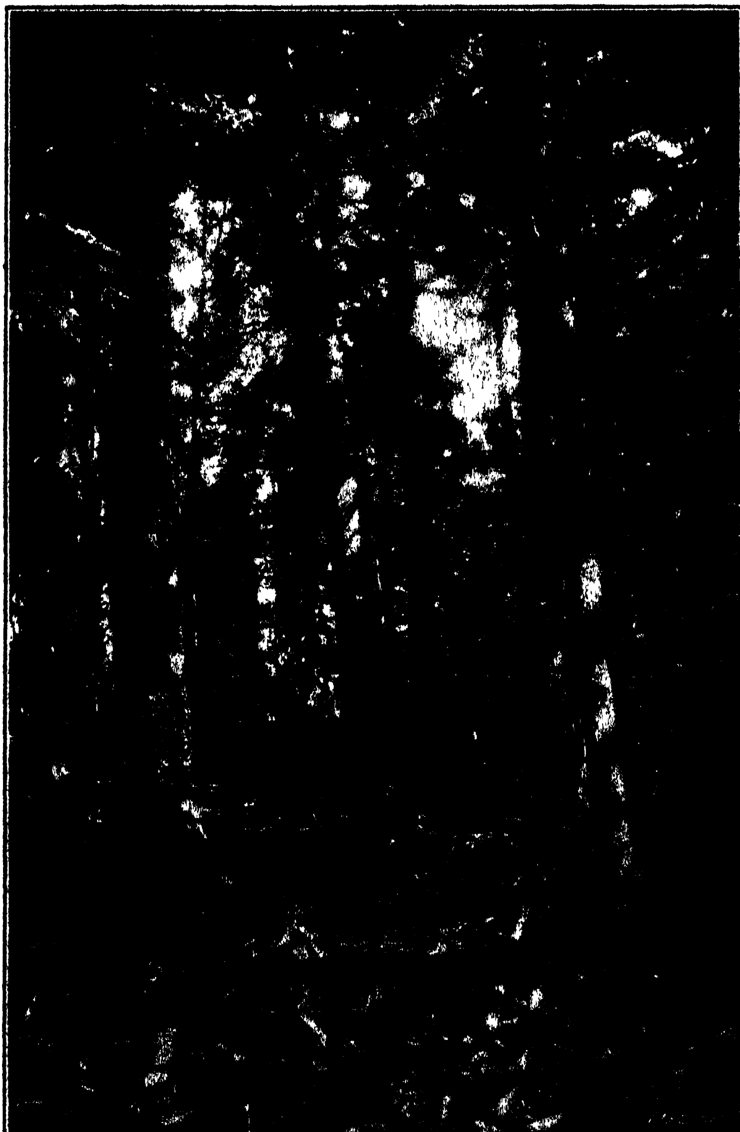
the glacial period came to an end. Then came disaster. In the increasing warmth, the forests of the south must have waged a relentless and successful warfare against their hapless northern rivals. Only those trees and plants could escape that could climb above the altitude limit of the prolific southern vegetation. This the spruce, among others, succeeded in doing, and became accordingly confined in this region to the highest summits and loftiest ridges, where, in the Southern Appalachians, it has persisted all these centuries and is found to-day.

The range of red spruce is thus decidedly limited, because of the relatively small area that is high enough to reach the bracing coolness and the plenitude of moisture spruce demands. The Southern Appalachians are themselves the remains of a plateau, once higher than the highest of the peaks remaining (6,711 feet). Composed of much soft rock, which weathered away, exposing the harder surfaces to a slower erosion, this plateau gradually lost all identity as such and took the form of the present mountain range, more than forty of whose peaks rise 6,000 feet and over. At this elevation the temperature is comparable to that of southern New England and the sub-alpine climate of the Rocky Mountains. Because of the greater elevation, however, the atmosphere is much more moist and the rainfall heavier. Here the red spruce has kept its hold, with its more wintry range-mate, Fraser fir. The latter, beginning in the uppermost part of the spruce zone, grows in almost pure stands of small extent, and is the counterpart of the balsam fir of eastern Canada.

WHAT KIND OF TIMBER WILL THE NEXT GENERATION YIELD?
This crew is running a regeneration survey to determine what the chances are.

Other compatriots of the spruce have also found lodgment, and in the lower part of the spruce belt the hardwoods and hemlock of the north mingle with the hardier species. Here all the vegetation is suggestive of Northern New England and Canada, while the true soil under the trees is covered by a spongy layer of plant remains known as upland peat, sometimes more than a foot in thickness, and frequently as acid as the peat of many of the Coastal Plain swamps

Successful in its warfare with nature, the spruce in recent years has found certain man-made circumstances too powerful for it. War between nations across the ocean has touched these spruce forests and decimated them, for modern warfare calls for aeroplanes and aeroplanes demand spruce and fir of the splendid quality so often found in these Appalachian stands. War and a growing population in the cities call also for more newspapers, and newsprint takes a heavy toll of spruce, wherever it is available. For these reasons a large portion of these spruce lands has been logged over, involving a great loss in streamflow protection and scenic value, and contributing but an insignificant amount to the nation's wood supply. What centuries of continuously hostile climatic conditions could not do to dislodge this valuable forest remnant, man has been accomplishing in a short span of years. The Appalachian



WHAT KIND OF TIMBER WILL THE NEXT GENERATION YIELD?
This is the kind which has been cut, fine red spruce and Fraser fir.

spruce is vanishing and may well become extinct if man does not repair the destructive work he has started there.

Details of the logging operations that are clearing off these forests will make the situation clearer.

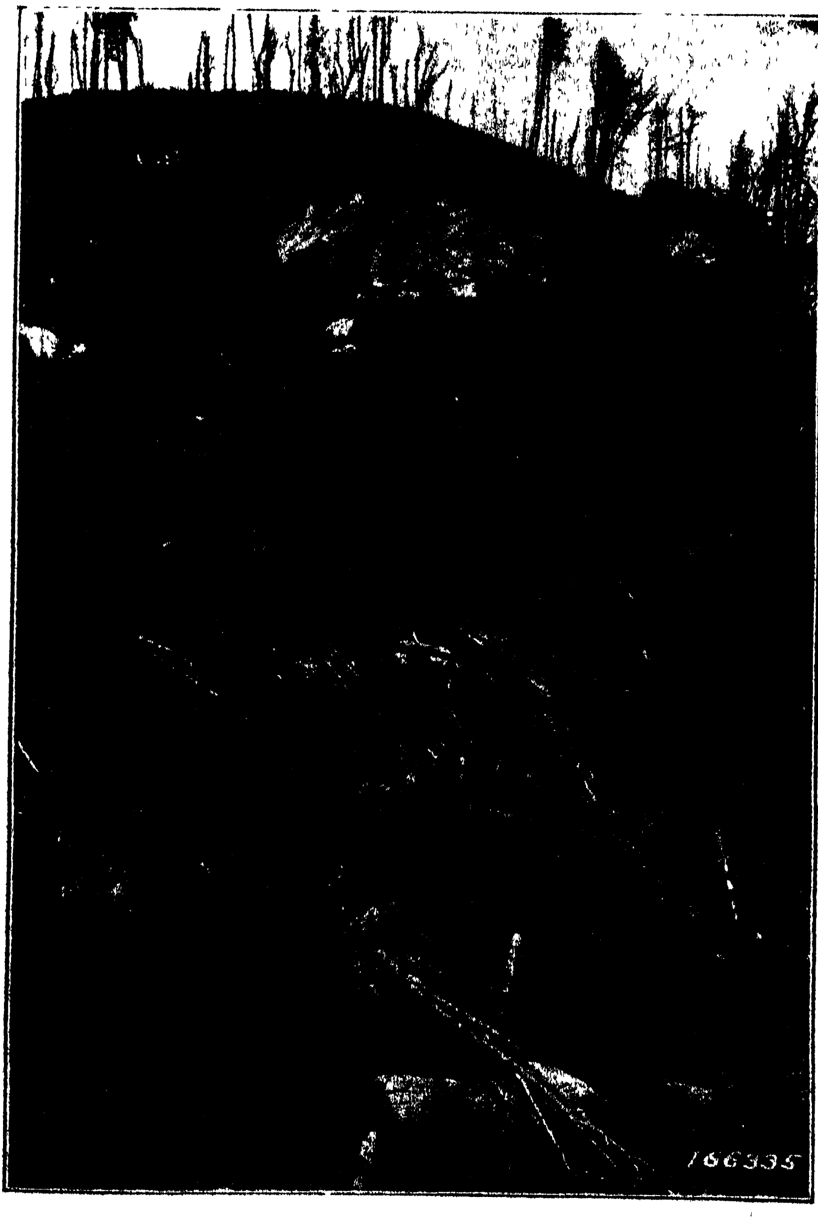
YELLOW BIRCH, A NORTHERN HARDWOOD,
near the upper limit of the Southern Appalachian spruce type.

A large portion of this region has been logged over, the spruce lands yielding a cut averaging from 18,000 to 30,000 feet to the acre board measure. In these operations the overhead skidder has been used to some extent to get out the material that lay above the logging railroads and at the heads of the flumes. On the steeper slopes dry slides are sometimes used and frequently the pulp-wood bolts are rolled down the steep mountain sides, a process locally known as "ball-hooting." Frequently, when the saw-timber has been logged from an area, the latter is "wooded," which means, in local parlance, that it is again cut over, this time for pulpwood. This second cutting removes trees down to about six inches in diameter. The slash left after logging is a fire trap, and the scarlet scourge—the ever-present enemy of young spruce—has taken its toll of the remaining small trees, leaving them as gray sentinels to mark the passing of the present generation. Where logs have been skidded downhill by horses and dragged uphill by the steam skidder, rain has within a year started to "gully" the mountain side.

What kind of timber, if any, can be cut from the next generation on such desolated areas? That is the important question which has confronted foresters and, to some extent, timberland owners with reference to the spruce-fir type. The forestry problems of this type are of a very difficult nature, and have called for some of the

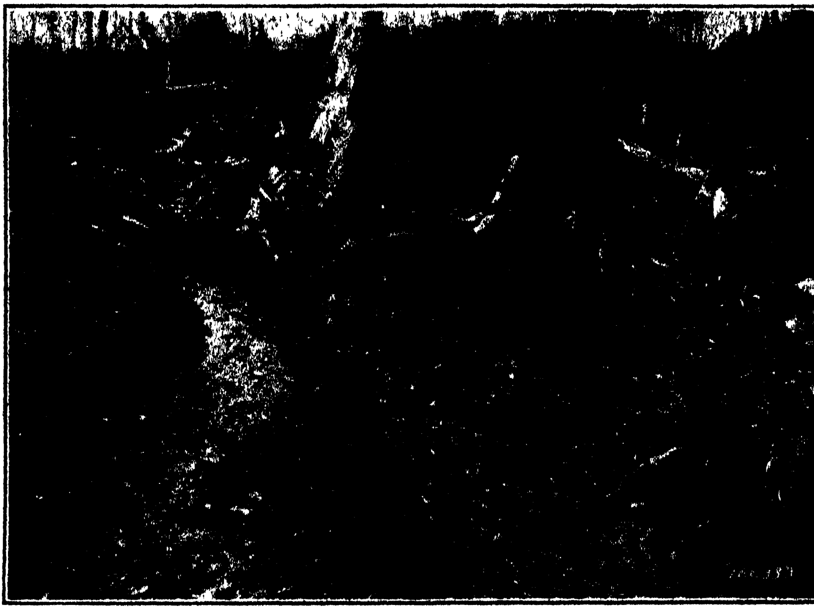
initial work of the Appalachian Forest Experiment Station, which the federal government has established in this region.

The Forest Experiment Station, however, is not alone in its interest in these tracts, and only this last summer was fortunately



Short and Simple Annals of the Spruce

1917—virgin timber; 1918—cut-over; 1920—burned; 1922—fire cherry and blackberry thicket.



THE MOUNTAIN SIDE
commencing to gully one year after logging (horse-logging, in this instance).

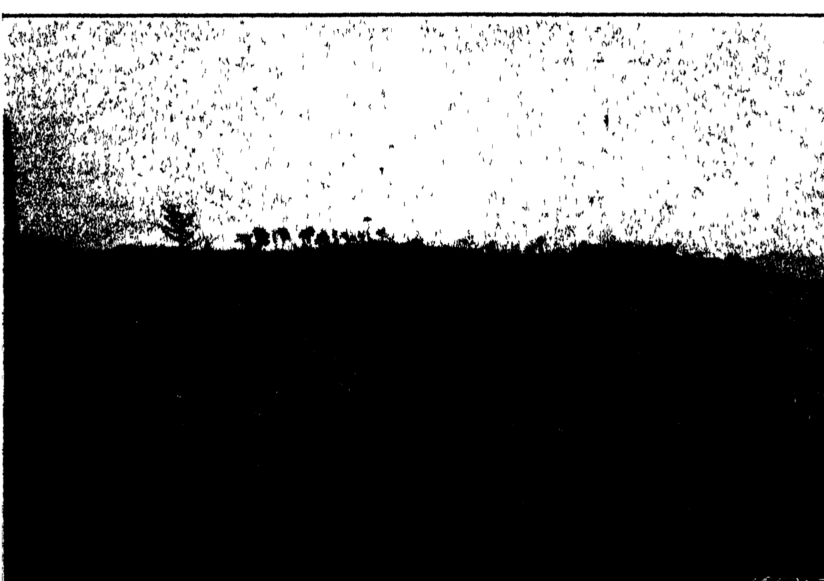
able to effect an alliance with other students of the Appalachian spruce problem, to their mutual advantage, and incidentally to the advantage as well of the "lost tribe." The opportunity was afforded through a field expedition to these woodlands from the Iowa State Agricultural College, at Ames, Iowa, consisting of sixteen embryo foresters and their two instructors. Engaged on a three months' expedition which included detailed tree observation and first-hand study of logging, mapping, surveying and timber estimating, the Iowa students were hungry for practical forestry of any sort. Sawmills, planing mills, paper pulp mills, acid extract plants, tanneries and veneer plants were to be visited in the course of the summer, but for a preliminary working-out they made their camp in the woods. Thus it was that they found themselves not many miles from a field party of four men from the Appalachian Forest Experiment Station who had already begun work on a so-called "regeneration survey" of the spruce cut-over lands, gathering facts and figures of the new growth actually appearing on these acres.

There is an affinity between foresters which a few miles of rough going can not dampen; so with packs on their backs the Ames foresters "hiked" over the hills to the native haunts of the red

spruce and the Fraser fir, joining the Appalachian Station field party in a several days' search for the elusive spruce and fir seedlings on cut-over lands.

The unexpected assistance made a 100 per cent. survey possible to the Experiment Station foresters, and was a valuable experience to the college men. Previous plans for the survey were immediately adapted to make the most of the opportunity. Strips 20 feet wide were run across the cut-over areas, literally gridironing them. All sorts of conditions, all slopes and all exposures were examined. The students, in crews of three, under the immediate guidance of a trained field assistant, tallied all the young trees down to the smallest year-old spruce seedling, recording also the old stumps, and gathering information on various general phases. To make certain that every spruce and fir seedling, no matter how small, was found, it was necessary to examine carefully every square foot of the strip

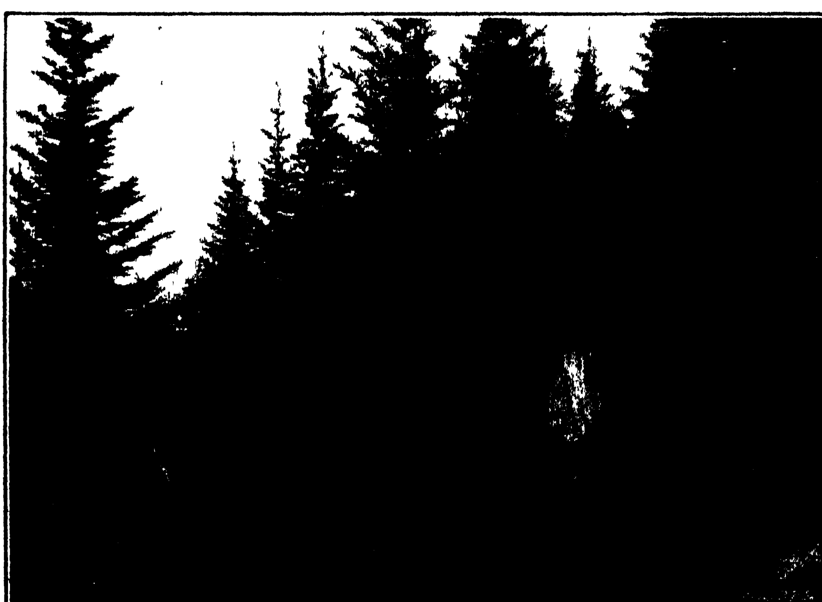
The result of this combined work, as well as that of the Experiment Station men after the young students had done their bit and gone on to other fields of experience, is a collection of figures and computations, dry-as-dust to every one but the forester perhaps, but of considerable significance as the latest, though it is to be hoped not the final, chapter in the romantic episode begun by the great glacier some six or seven hundred centuries ago. Whether we shall write "Finis" to this tale within the next half century,



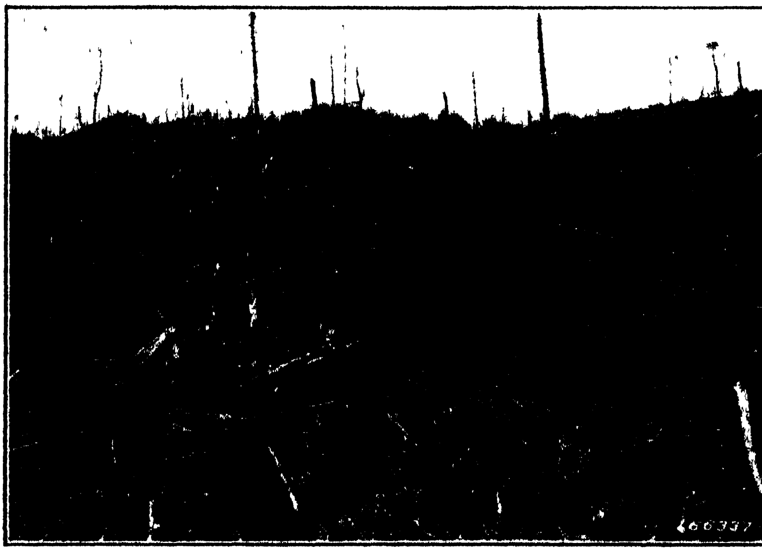
At the Intersection of Two Skidder Lines.

Nature may save the situation unless fires come; but the odds favor the fires.

THE SPRUCE VANISHES IN THE PAPER AMERICA BURNS.
Forestry students measuring spruce and fir pulpwood before it is shipped to the pulp mill.



WHAT THE GOVERNMENT AND ALL FORESTERS DESIRE—
splendid 25–30–year old stand of red spruce and Fraser fir reproduction on cut-over land.



AFTER MAN AND HIS MACHINE HAVE LEFT,
the "Scarlet Scourge" takes its toll. Cut-over spruce land burned in 1921.

or whether we shall continue it indefinitely and to our very obvious profit, depends upon the immediate action taken as a result of these observations. To round out the present account, a summary of all these findings may not be amiss.

On the cut-over spruce lands where fire has not burned, the young trees are coming up satisfactorily. These trees were seedlings before the cutting was made. New seedlings, dating since the cutting, have not yet appeared save on the older tracts. Altogether there is enough of this young growth to continue to hold these lands for spruce, if fire does not intervene; but there is not enough to result in fully-stocked stands in this tree generation.

Where fire has come, even though only once, the cut-over lands are in a hopeless condition, so far as spruce is concerned. Blackberry and raspberry briars overrun these acres, to be succeeded by fire cherry and yellow birch, which according to count run several thousand an acre and in this region are of no commercial importance.

Only occasionally on these burned areas are live young spruce found, and then around springs and seeps, or along streams, where the small advance growth of seedlings and saplings escaped, evidently because the fire was halted or because it was unable to burn the upper layer of soil where seeds were stored.

All told, it is evident that the amount of new growth is entirely inadequate for a future stand of softwoods on by far the greater

AMID THE GRAY SKELETONS OF THE SPRUCE,
jungles of briers, fire cherry and yellow birch grow up.

number of these spruce burns. If new stands of spruce and fir are to be available within a reasonable time, the slow and expensive method of planting must be adopted.

Most obvious and most important of all is the fact that adequate fire protection must be put in force on this cut-over land; otherwise what is true of these spruce burns will soon be duplicated throughout the length and breadth of the Southern Appalachians. In that event, the cool mountain streams flowing from hidden springs among the spruce-covered rocks, and inviting alike the hydroelectric engineer and the profitable tourist, will cease to flow. Down gullied, barren mountain sides spring torrents will rush, destructive and profitless to any. Throughout the summer no even flow will be preserved; no wheels will be turned; no hiking pleasure-seeker will find here the refreshing invitation that brings him to such regions. With the vanishing spruce, the good that it has done to the mountain communities will vanish with it. Though strayed far from home and though driven to the heights to maintain itself at all, the Appalachian spruce has paid its way these many years, has made itself a good citizen and friend to man. Now, in its direst extremity, turn about is fair play: the perpetuation of the spruce type in the Appalachians is the duty of every human citizen and friend of the forest. As matters stand to-day, the loss of this tree is far too imminent a possibility.

THE REVIVAL OF CLASSICISM AND THE LEGEND OF SOCRATES

By Dr. JONATHAN WRIGHT

A BOOK[1] remarkable for its research as to the sources of Plato has recently fallen into my hands, fresh from the press of Belgium. While it deals very little with the Nature Philosophers, who preceded him, but rather with the sophists and rhetoricians who formed the intellectual background in the life of Athens in the youth of Plato it has its interests for science. It incidentally sets forth the waves of mental activity which succeeded one another in the wake of the Ionian cosmologists. It is the product itself of the new interest in the classics and the story of Greek civilization. The book furnishes an illustration of the shifting of the currents of thought in our modern world and has a significance in itself. How far the wavelet of the modern revival of classicism is going to carry us it is at present impossible to say. It is interesting at least as a cosmic phenomenon and is worthy of the attention of psychologists and of sociologists alike. As remarkable as it has been, when so many of the practical results of materialistic research have emphasized the triumphs of science it has come with a suddenness which makes it seem unreal. Science has looked askance at classicism, with hostility even, since the time science began to knock insistently at the doors of universities and found classicism and the indifference, even the hostility, of the public barring its way to academic honors. It is hardly a hundred years since Mr. Pickwick was exposed to the widespread ridicule for having made the archeological discovery of

Bill Stumps
x
His Mark

reported by Mr. Dickens, who also in the same narrative told of the effects of a supposed electrical phenomenon on the bald head of an inquisitive scientist, when it really had its source in the ready fist of Mr. Samuel Weller. Since the days when Mr. Dickens found it highly amusing and very lucrative thus to furnish laughter to his generation, scarcely three generations of men have passed away and for half that time archeologists and physicists, busy with elec-

[1] "La légende Socratique et les sources de Platon," par Eugène Dupréel, Bruxelles, 1922.

trical phenomena, have sat in the temples of fame and in the esteem if not the affections of the public. No one mocks them now, but there is undeniably a check to the exuberance of the hymns of praise for science.

The nature philosophers of old Greece came and went with scarcely less suddenness, and Aristophanes hung one up in the air in a basket on a wall at the theater for people to laugh at. It was not really a nature philosopher at all. It was an unusual philosopher. It was Socrates and he enjoyed the joke. Some of it was on Aristophanes, for Anaxagoras did not captivate Socrates as he did Pericles. The Athenians chased Anaxagoras out of Athens and they put Socrates to death. The Sophists had their day before Plato, and from Plato to Mr. Grote scarcely any one has given them a good name. Sophistical is a word of anathema, but the sophists were not bad fellows and were vastly more popular once than Socrates. The shifts of intellectual currents, the eddies of the mind of man in the mass are mysterious. Classicism coming back now may be one of them. One naturally asks a cause for this and the first response one hears is that it is the result of the unsatisfactory nature of the state of our spiritual affairs, the ethical, political and social status in which the world finds itself from following too trustingly the leadership of science. This is entirely too radical and too simple, though there has unquestionably been a chilling in the air in the attitude of the public mind toward science within the last few years, despite a rather awkward propaganda on the part of its friends. The benefits conferred on mankind, despite all the exaggeration and narrowmindedness of the appeal of the propaganda, has been too obvious for the world to disregard and turn elsewhere for a stimulus on that account. Man does not live from bread alone, it is true, but materialism has at least supplied a very large amount indeed of the necessities and comforts and perhaps has not been entirely recalcitrant in supplying some of the spiritualities of life for a generation past, but another generation approaches.

As a matter of fact, however, a love of the classics has not been dead. It has not even perished from the college curricula. It has ceased to be the somewhat superficial decoration and callow boast of the recent graduate in university honors, but there are men still alive or but recently dead who have loved Latin and Greek for their own sake all their lives long. In the intellectual life of France and England a hundred years ago the study of them was the occupation of the diligent and in social and political life distinction was with difficulty attained without at least a pretence to acquaintance with them. It happens that modern democracy arose and kept step with

the progress and the triumphs of science, and it was natural to suppose that both were more or less responsible for the decay of a knowledge of classical literature. Science has been, aside from certain bigots who infest every territory of thought, prompt to welcome a return and to disclaim any hostility to the study of the classics, but in this its historians are a little disingenuous. Democracy however has been ultra-scientific and has only of late given token that it too is looking towards an endeavor to place the study of the classics on another footing. But a short decade ago its eyes were exclusively fixed on the promise held out to it by science. In it democracy found its idols.

Has the great war disclosed their feet of clay? It is western Europe on which the blight of war has fallen most disastrously for civilization and it is France which again leads the intellectual world on the path back to the classics. The interest of American educators is but an echo of what is taking place in France. Education and public instruction there, as nowhere else, is a function of the government actively employed in its direction. There under a democracy which seems in many ways to have presented its worst facets to view educators are filling the school curricula with new courses of the classics. In England is observed under other aspects, but not so decisively, the same tendency, hastened rather than halted by the advent to political power of a government which is socialistic in its democracy. Lord Cromer, the conservative, Gilbert Murray, the liberal, have long upheld the tradition transmitted by Gladstone from an earlier generation of statesmen to a later; and now the avowed socialist, Ramsay MacDonald, has been urging in Scotland that educators instil the classics into the children of the common people, because he says unless higher education exists below as a stimulus it can never enduringly bloom at the top. You must exercise the wits of the people, if they have any, by interests in intellectual life. That is the only hope of modern democracy.

Herbert Spencer objected to the introduction of the metric system because it would exercise the wits of the people less to figure daily their weights and measures and prices in decimals than in the pounds, shilling and pence and the awkward standards which still exist there as with us. Socrates in the "Phaedrus" questions the advance made in civilization by the invention of letters. He tells the tale of their having been invented by Thoth in Egypt, who in the presence of King Thamus demonstrated their value to man in the cure of their folly and forgetfulness. The king doubts the wisdom of it. King Thamus, or Socrates for him, replied that letters in supplying the means of enduring memoranda enervate

the memory by taking its place. All these great men, Spencer, Socrates, Ramsay MacDonald and King Thamus, had the same goal in view—that of sharpening the wits and adding to the intellectual values of their fellow-citizens. The qualifications of the guards of Plato's "Republic" were chiefly educational. By the guards or guardians he meant the governing classes. They should be educated to know not only evil in the concrete when they saw it but evil in the abstract. They should receive the highest education possible.

Herbert Spencer, the last champion of the Manchester School, Socrates, the master builder of Plato's "Republic," and the socialist premier of England seem to have come together from the ends of the earth and the remoteness of ages, but in the mind of MacDonald existed, when he talked to the universities of Scotland, what is at the back of every intelligent man's mind, who stands at the crossways of modern democracy. He looks down all the paths of history and sees the wrecks the proletariat has made of social organization in more than one civilization and he holds desperately to the hope that here in America, where education is the law of the land, compulsory for every child, because any child may stand here where Ramsay MacDonald has in England, we may be training a more enduring democracy. The aristocracy of England built a mighty empire and has handed it over without bloodshed, with hardly a tremor to shake the ship of state, to an ultra-democracy. That is an achievement in itself almost unexampled in history. It was accomplished largely by virtue of that *sophrosyne* which Socrates taught in Athens twenty-four centuries ago. As we stand a little bewildered and much alarmed at those crossways of modern democracy, what better thought occurs to us than to teach our children the legend of Socrates?

By virtue, not of science, but of that wisdom which the history of mankind and the experience which it has gained since Socrates, whose seed fell on fertile ground, monarchy, oligarchy, autocracy, aristocracy have proved more enduring than any real democracy which has ever arisen. Along with science for his material welfare, along with religion for his spiritual nature, we must supply our republic with the sophrosyne of the ancient philosophers of Greece which mellows and broadens the mind. I fancy this train of thought has had something to do with the renaissance of the classics. It is rather this, I imagine, than the chill alone which is undoubtedly in the air for science when men think of the ghastly work it did for the destruction of millions of human beings and how since the war it has shown the same tendency to hide behind

locked laboratory doors as it did before the greatest catastrophe the world has ever seen. Men think of it as preparing a still greater one for the future and they shudder. They shrink from the law of the survival of the fittest to resist poison gas and dodge death dropping from the sky and lurking beneath the sea. They know very well what hatched these horrors of war. It was science. The evil in men seized upon them, but it was science furnished them as well as the innumerable benefits with which it has blessed mankind. Happiness, however, is of the spiritual nature of man, not his material comforts and the banishment of many of his physical sufferings for which he has alone to thank science, and now it has turned and inflicted hitherto unthinkable agonies.

There has been much talk of this kind in the last five years and it is very probable that in a way civilized man, as he is known to us western folk, in leaning away from science, first towards a sort of abyss of despair and pessimism, is now leaning toward the classics as hope springs ever anew again in his breast. When one tries to chart the broad sea of the soul and mind of man in the mass one can only deal with surmises. At any rate I lay down this book by a Belgian professor at Brussels and think of devastated Belgium and its heroic king—not a democracy exactly. I can only grope toward the opinion that deep in the psychology of vast numbers of intellectual people there is a revolt, largely inarticulate, against science, which promised us happiness and gave us misery. We were expecting bread and we got a stone. War is the father of all things and in so far science stood, if not as an enemy, at least in antithesis to the classics. The strong revolt against war carried with it some revolt against science and perhaps moved men a little toward the classics. In so far as this was influential the renaissance of the classics in the esteem of men will not be very durable, but as we said, it depends for its rise on something more stable than a temporary coolness towards science.

This is a fine book instinct with the scientific spirit of modern research applied to a profound and ingenious study of the origin of Platonic philosophy. If it is a revolt from science it has borrowed from it a thoroughness of method which even in science itself is more honored in the breach than in the observance. Dupréel's tendencies are still more toward this breach in resting many of his conclusions on an insufficient basis of trustworthy fact. Despite the fact it is a work intended not only to study how far the real Socrates differed from the Platonic Socrates but, as the title indicates, to elucidate the sources of Platonic thought, the author does not make it very clear how much or how little the Nature Philoso-

phers had contributed to the groundwork of such knowledge of natural phenomena as Plato possessed, especially as to the physical basis of the thought associated with the senses. He does not point out with sufficient emphasis that Alcmaeon had already furnished the brain as the depot to which the five senses bring their messages. Though it was not accepted by Aristotle, who clung to the theory of Empedocles that this depot was the blood or its central chamber, the heart, nevertheless it was a theory of the predecessors of Plato, which the latter adopted. Nor does he make very clear how obscure was the idea of the synthesis of the senses from which most thought springs, how indeterminate was the line where sense cognition ends and thought begins—how indeterminate it still is. If he had done so the reader would then be in a position to appreciate what Plato added to what he inherited from his predecessors and that is the aim of the book beyond the mere legend of Socrates.

As pointed out by Beare[2] Plato takes this point up in the "Theaetetus" and states the problem clearly in the declaration that we do not see with the eyes nor hear with the ears, but through them. Aristotle did not advance the exposition of the question very much by inventing the term *common sense,* standing apart somewhat from the senses but made up of a synthesis of them all. It is mere logomachy, like his entelechy. Wrestle with the thing as we may we do not bridge the chasm yet. We know there is a connection of mind and sense, of feeling and sense, but what it is still defies definition just as thought itself does in a physical way. This may have been, doubtless was, a problem vaguely apprehended by his predecessors, just as the reality of Plato's "Ideas" can be traced out in the fragments we have of Pythagoras and behind him they disappear in the Orient. What Plato did add to what he had from Pythagoras, quite aside from his "Ideas," was the fact that not only is the mind the engine to utilize the stores the senses bring to the brain which memory guards, but it itself is the source of a sort of cognition which leads us to what is virtually metaphysics.

It is too often forgotten in accepting the current definitions of science that mathematics is a part of it and there is and always has been reason for arguing that mathematics do not rest purely on the testimony of the senses or the sequence of reasoning. They depend primarily on certain axioms from which there is no escape. We see the apples on the tree and note their form and color and the way they grow and the season in which they ripen, and if we have seen a lot of different kinds of apple trees and have classified them,

[2] Beare, John I., "Greek Theories of Elementary Cognition," Clarendon Press, 1906.

if we are a pomologist, or only a farmer even, we know the name of the variety. But if we want to know how many there are, though memory of past experience comes to our aid, we have to count them. We resort to a faculty of the human mind, how acquired we do not know. The embryologist can trace out the organs of the senses developing with the brain in the embryo, but what makes us able to count as well as smell we do not know. This faculty like that of sense depends for its efficiency on exercise. The dog and the tea taster have wonderfully increased their efficiency beyond that of the rest of us, but they both make mistakes. It is not only mortal to err in this way, it is even canine. But figures never lie, whatever the figurer may do. The ends to which the art of figuring may bring us are so far beyond the possibility of sense evolution that they flatly contradict sense, they outrage it in every way. Protagoras taught us man is the measure of all things, but these are only what the senses measure. Figuring has taught us indeed that "things are not what they seem." Now Plato did just that when figuring was in its infancy. He showed us clearly that the knowledge of number is quite aside from our knowledge of form and color. Dupréel traces the thought back to Pythagoras, to that time of vagueness in the differentiation of the senses from thought—when we thought with our blood and as every event has its antecedent this very likely is allowable, but to dig the diamond out from the dross is a more stupendous work of genius than finding a diamond mine. Pythagoras recognized the mystery in number and called it divine. In its origin we still recognize its mystery. Its separation from sense by the Pythagoreans and Platonists alike is emphasized in the asceticism of their followers.

As Gomperz[3] puts it, there is nothing prevents us from thinking a swallow of water may moisten our throat, but that it will bring us no refreshment, yet it is quite impossible for us to think the part greater than the whole, that twice two is other than four. Plato in the "Euthyphro" and the "Republic" first defines exact science as resting on just this—the weighing and the measuring and the counting thus involved. The medical man and many another man of science has to depend on "feelings" and the testimony of the senses and even the higher mathematics can not entirely divorce itself at the start from the facts of astronomy revealed by the senses if he is to follow Newton and Einstein, but it advances chiefly by mathematical formulae, essentially based on quite a different faculty. We have passed far beyond the testimony of senses in our knowledge of the microcosm and the macrocosm and it is entirely

[3] Gomperz, Theodor, "Greek Thinkers," tr. by Magnus, iv vols., 1908–1912.

incorrect to say we know all we do know from that. Of course there is little dispute as to this, but habit forces us to appeal to the senses to confirm the end results of the formulae and thus acting often at one end sense confirms what it denies at the other. In so far as reasoning is based on the senses the processes of thought are as often at fault. The synthesis of the senses, *"common sense,"* helps us not at all. "Realities," whatever they are, escape our grasp with the help of these alone. Certain arithmetical and geometrical propositions we must accept without reasoning and without the testimony of the senses. In the order of these Plato places his "Ideas" as realities.

To the reader conversant with all this possibly the failure of Dupréel to develop it will be no loss, but his exposition of Plato's thought, whose source in this matter may be in Pythagorean doctrine, without it is apt to make small appeal to the less informed reader. The modern student of moral philosophy will fail to follow him when among these "realities" he places our notions of the good, the true and the beautiful. We place the conceptions of these in the collective sense of "the tribe." Justice also varies with longitude and latitude and time relations to them. Like the color of man's skin, what is true for one is not true for another, nor his idea of the good nor his notion of the beautiful nor what is due from one man to another. But when we come to mathematics twice two is four is as true in Alaska as in Patagonia, and it doesn't depend on the senses at all. It does not depend on the religious or political or ethnical view of truth at all prevailing among Esquimaux or Patagonians or exactly at all among people of much higher culture. It all goes back to simple counting—geometry and much of astronomy. We know the sides of a triangle subtend two right angles. We can take some calipers and "prove it," if we wish, by sight, or we can divide a square into four smaller squares and draw a diagonal from corner to corner and count one right angle and two halves, by seeing it is true, but in the mind lies the faculty of number which is independent of sight. Whether this exposition truly represents Plato's thought in the "Theaetetus" or not it is open to criticism, and whether the doctrine is true or not it makes small appeal to those worn with the disquisitions of a thousand philosophers since Socrates. By clothing it with some of the thought that is afloat to-day I have tried to familiarize it in such a way as to illustrate how, in other ways no doubt, it was familiar to the contemporaries of Socrates, for the path we have seen leads us back to Pythagoras and the divinity he quite plausibly makes of number. It is fundamentally a mysterious thing and man always

makes his gods out of mysteries. Vitalism has become a fetish with some, with some the germ plasm.

Dupréel assumes among his other conclusions from the "Dissoi Logoi" and other fragments, which have come down to us of those sophists before Plato, that Plato has made out of a real Socrates a mythical Socrates, which is probably true enough (even Plato can not portray a man to the life)—a Socrates superior to Protagoras who, according to Dupréel's interpretation of the information he derives chiefly from Plato, was a very superior person. As a matter of fact, however superior we infer from Plato Protagoras was, we are left to infer from the same source Socrates was supreme. Why accept one inference we get incidentally and reject the other we get from the author's evident design? The gist of many of the arguments is not beyond any one's comprehension, if clothed in the language which is redolent of contemporary thought in any period of culture, as the history of thought teaches us. Why was this refutation of Protagoras too much for the real Socrates? Dupréel is at pains to explain to us that Plato created Socrates very much as God created Adam—out of the dust of sophists. It is the art of Socrates which we are willing to believe Plato has heightened, not necessarily his mental acuteness in refutation of the doctrine of Protagoras in the "Theaetetus" that man is the measure of all things. Around this refutation is the play innumerable of thoughts which lead us to the answer to a doctrine which was old in the world even in Socrates's time.

Whether or not the real Socrates added anything new to the refutation it is impossible to say, but when Dupréel goes so far as to intimate that Plato and even Aristotle had no originality of their own he loses the ordinary sense of words. There is always an origin back of an origin, a cause back of a cause. It is well to drop such a conception from dialectics and think of thought historically as an impersonal process in which vast numbers of minds have participated and which only a few have illuminated. The greatest of these was that of Plato and the greatest work of art of Plato was Socrates as he appears in the dialogues, whether he created him or only illuminated him. For Plato to have created Socrates, as Dupréel seeks to show, like Adam out of mud, and to have had no part in the *Word*—in asking us to believe this Dupréel asks too much, but to say that the IVth century B. C. developed the ideas of the Vth century B. C., is something which might be said of every century. Socrates's death (399 B. C.) marks the beginning of the IVth century and to say as Dupréel does that Plato and Aristotle worked over the material of the Vth century,

great as it was, the age of Pericles, without adding anything to it, is suggesting something to which few will subscribe. But if that is so, Socrates at least belonged to the great century. Did Plato create him in the IVth century or did he grow in the greater century, as Dupréel calls it, and did Plato in the lesser century create a Platonic Socrates greater than the little Socrates in the greater century, a real Socrates, who captivated the mind of Plato, who knew him, and engaged the thoughts of Aristotle who lived in his tradition?

It is a commonplace of the history of ancient Greece to say that the age of Pericles was the acme of its glory, the age of Socrates. Dupréel falls in line with this sentiment, but to say that Plato and Aristotle were its heirs and that is all they were, as sometimes appears in his ardor to ferret out their predecessors, is doubtless going beyond his own thought. The rapidity of the waning of the power of philosophical thought after Aristotle may indicate that it had begun even before Plato had produced his best work. It is very probable that this is true. It indicates how powerless the mightiest minds are in the face of cosmic change, dependent on vastly more than the superiority of two or three individuals, but at the end of Dupréel's book he turns on Aristotle as well as Plato. He makes them both little better than the shapers of their predecessors' thought for eighty future generations of men. This book of the learned Belgian professor is one of very high merit and of absorbing interest, but this is nonsense.

SOME FEEDING PROBLEMS OF CHILDHOOD

By Dr. C. HILTON RICE, Jr.
MONTGOMERY, ALABAMA

In The Scientific Monthly of December, 1920, Stefánsson, the Arctic explorer, reported some interesting observations made on feeding habits of men and dogs in the far north. He noted, for example, that the better bred man, one who had had opportunities of tasting a wide variety of foods, would more readily adapt himself to a radical dietary change—in short, was willing to try any food once. On the other hand, the poorer bred man who had been brought up on more or less restricted diet was most unwilling to try new foods. In his experiments with dogs Stefánsson observed that a pup fed on tainted meat for several months could not be induced to eat fresh meat. Also the puppies fed on fresh meat would not eat tainted meat. In both cases some of the dogs starved for a week before they would accept the change in diet. One of the dogs actually starved to the point of death and was saved only by a return to his accustomed food. A further observation was that a young dog that had been fed on a variety of foods, scraps from the table, etc., would readily eat almost any food offered.

To a striking extent I have seen these food reactions exhibited by the human young. In fact, to overcome food prejudices is perhaps the biggest problem in the feeding of children. Time and time again I have seen children who had reduced their own diet to a few—or even one—articles of food that could not be induced to taste other foods. A case in mind is that of a six-year-old boy whose diet consisted exclusively of cold biscuits. I was assured by the father that the child had taken no other food for several weeks and for some months he had declined to eat fresh vegetables and milk. Another case was that of a three-year-old child whose daily ration was a can of Eagle Brand Condensed Milk. Deprived of the condensed milk, this child starved for five days before he would take other foods.

There is an old belief still held by thoughtless people that instinct will guide the child to eat the foods it needs. In short, what the system naturally craves is best for it; what it dislikes is harmful. There never was a belief which has less foundation and fact than this. Every day of my life I see children who have appetites only for the foods that are slowly wrecking their health. Every

day I see children with positive prejudices against the foods that would give them health. The child who has the fewest food prejudices enjoys the best of life, because it is food more than any other environmental factor which guarantees physical well-being.

There is a rather common type of child who, allowed to eat what they like, will turn invariably to carbohydrates and the between meals eating of candy, cakes, etc. Such children from frequent eating are never really hungry. Owing to the character of their diet they become constipated. This slowing down of intestinal activity brings about a delayed emptying of the stomach which results in food retention and hyperacidity. It is the presence of this residual food in the stomach which destroys the child's appetite, and it is the hyperacidity which causes the pain in the "tummy" of which this type of child so frequently complains.

A solution of the problem presented here seems perfectly obvious. It appears to be merely a matter of giving diet lists and careful instructions to parents. However, the problem is very much more formidable than it seems, for it is deeply woven into the fabric of modern civilization. It involves a complete change of habits, and to change human habits is almost as large a task as one can undertake. To change the feeding habits of the child requires a changing of the parents' habits of dealing with their child. For a child that is allowed to eat anything that it likes, and at any time it likes, is almost invariably a spoiled child, and the spoiled child is a difficult case to deal with. To me he is a most pathetic and lonely figure in life, for nobody loves him except his parents and grandparents. But the fault is not his. The responsibility rests upon his parents. If they can not alter the relationship and gain control over the child's habits there is small hope of success in feeding such a case. However, if the child himself is a rational being, good results may be obtained by dealing directly with him. The number of such children that can be dealt with successfully depends upon the tact and patience of the physician.

For some years I have been preaching to parents the extreme importance of gaining control over a child in its second year. We long have known the perils of the second year. It is the most critical age of life, for it is the time when the foundation of food habits is formed. If a child gets off wrong, if he acquires dislikes for essential foods, these habits are likely to become fixed and permanent so that his whole future is affected. The longer I observe children and people in general the more I am convinced that many of the ills of middle life, constipation, visceral ptosis, chronic indigestion, gall stones, hypertention, gastric ulcer and gastric cancer

often have their origin away back in that remote period of childhood when, all unconsciously, the very foods that would have guaranteed long life and good health were excluded from the diet.

If ever there is a time when the firm hand of discipline needs to be used in the training of a child it is in this early, irresponsible age when the child is tasting his adventurous way through the lists of foods that make up the human diet. Here is the time to put into their little systems the A, B, C's of the vitamins which will protect them against more ills perhaps than we have yet suspected. Certainly there must be many border-line nutritional disorders which we can not recognize, yet which are due to a deficient vitamin or mineral content in diet.

It is not my purpose here to discuss the treatment of the individual case. I want rather to stick to the larger phases of the problem as they relate to preventive medicine. It isn't hookworm or malaria that is the plague of the south. It is malnutrition. Go to any school and watch the children as they file in or out and note what a small percentage are rosy and robust; how few look as children ought to look; how very few of them have the vigor and stamina and bloom of health that characterizes the wild creature that is nurtured by nature instead of by man. Observe their food habits and you will see the cause. They look exactly like the trash they eat. They remind one sadly of scrub cattle that have seen a hard winter on cornstalks and dead grasses.

In such a group of children one sees all grades of malnutrition, from slight anemia to actual illness from chronic gastric and intestinal indigestion. A symptom I have noted particularly is the marked extent to which the deficient diet is reflected in the child's temperament. A peppy, high-strung child may lose interest in life and sink into a mental state of moody or placid indifference; or a sweet-tempered child may gradually become extremely irritable and rebellious. I have had mothers note this symptom many times, and I often have observed a remarkable change in disposition follow a return to the normal diet. Since many of these cases are not treated at all or are treated unsuccessfully because of the lack of intelligent cooperation of the parents, there must be many children who pass into adult life with temperaments considerably changed from what they should have been.

There is a distinct type of malnutrition that is not uncommon, the spry, bright-eyed, sparrow-legged child with a bird-like appetite who feeds frequently on small amounts of an unbalanced diet. He is tense as a watchspring during the day, and his brain appears to dissipate energy at the expense of his body tissues. Of nights he

dreams, rolls in his sleep, grits his teeth and is up with the dawn to continue his high tension existence. To him food is merely something to relieve the physical discomfort which other people recognize as hunger. He passes on into adult life, and soon or late he discovers that he is hopelessly out of harmony with life. He then shows up at the office of the internist, who recognizes that the poor creature has been living on his nerve and mesenteric fat. The doctor puts the patient on a food and rest cure. The patient stores up a little reserve energy and a few pounds of fat, then he grows tired of rest and the eating of foods he never did like, laughs at the doctor and hits the trail again. In a short time he is back again in the clutches of his old food habits.

Right here I want to call attention to the tendency of mal-fed children to get back on their old diets. The longer a child has been on a one-sided diet, the stronger become his food prejudices and the more difficult it is to hold him to a balanced ration. It seems as though his tissues and organs become specialized, as it were, to certain kinds of foods, and always there is the old subconscious pull of habit that drags him back to his old ways of eating. That is why it is so difficult to feed the older child whose habits of diet have become fixed. That is why it is so extremely important to start the child on the right foods at an early age. To get this fact before parents is one of our duties in preventive medicine, for it is easier to prevent malnutrition than it is to cure it.

From what already has been done for the general welfare of the child there is good reason to hope that mothers in general will come to know more of the art of good cooking, and that both mothers and fathers will learn more of food values and the urgent importance of the early training of children to proper dietary habits.

Here in this land of plenty, of sunshine and fresh air, of milk, luscious fruits and fresh vegetables, of fresh eggs and fresh meats, it seems a crime against nature that any child should walk among us with the blight of malnutrition upon him.

SOME RIDDLES IN EPIDEMIOLOGY

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Riddles (A. S. *raedan*, to interpret), probably the oldest extant form of humour. They spring from man's earliest perception that there are such things as analogies in nature. Man observes an example of analogy, puts his observations in the form of a question, and there is the riddle ready made.[1]

THAT there are riddles in epidemiology as in any other field of applied science is beyond peradventure. That it is often useful and sometimes necessary to list them and to examine them appears equally certain. Granting the chance that the stated or assumed analogy in the riddle may be fallacious, progress may follow as hard upon contradiction as upon elucidation.

We may say with Mr. Augustine Birrell that we

> should not have ventured to introduce our subject with such very general and undeniable observations, had not experience taught us that the best way of introducing any subject is by a string of platitudes, delivered after an oracular fashion. They arouse attention without exhausting it, and afford the pleasant sensation of thinking, without any of the trouble of thought. But, the subject once introduced, it becomes necessary to proceed with it.[2]

We may consider that epidemiology, conceived in a narrow sense, is the study of the unusual prevalence of communicable disease in a population: it is the study of the natural history of epidemic occurrences of infectious or contagious diseases. I have said "in a narrow sense" advisedly for reasons which will appear shortly and which are related particularly to the unfortunate connotation which seems to restrict it entirely to the *unusual* prevalence of disease. In administrative epidemiology it is a matter of concern to determine the nature of the disease whose prevalence is considered unusual (minimizing by oversight for the moment the problem of first determining that an alleged pathological condition is unusually prevalent), and then to approximate an understanding of the pathways of infection. Epidemiological study must also consider the variables which enter as factors in the determination that a particular individual becomes ill and that his companion escapes the malady, that one sick person dies and another recovers, that one who has

[1] Excerpted from that much maligned but serviceable institution, the Encyclopaedia Britannica, eleventh edition, p. 316.

[2] "Obiter Dicta"; 1887, N. Y., p. 58.

suffered the visitation of an illness before appears to possess a hypersusceptibility to reinfection and another an immunity.

The great plagues of antiquity or our recent world-wide outbreak of influenza furnish us with examples of epidemics whose prevalence was so wide, whose severity so great and whose pathological picture in the infected individual so striking that their existence and their identities were unmistakable. Fortunately, great epidemics are comparatively unusual occurrences. It is not with them that the administrative epidemiologist is generally concerned. His attention is, and of necessity must be, continually focussed upon those epidemics which are always with us in civilized communities and which are sufficiently mild, localized or delimited in point of place, time or population group to be unrecognized except by the trained observer, which yet threaten significantly the health and the welfare of the community at large and which may, for lack of suitable combative measures, become widespread and devastating. This applies to communities in which sanitation is effectively practiced as well as in less advanced places. To go only one step further, then, a logical consequence of any program of *preventive* epidemiology is the continued study of the usual or normal occurrence of a particular disease which may or which from time to time does break out in epidemic proportions.

If we accept as a basic tenet of parasitology that for each particular infectious disease there is a specific causative micro-organism, it may appear to follow that wherever and whenever there are new cases of a particular infection there have been precedent cases of the same disease. And it was an accepted belief for a long time that fresh cases of a disease in a community, whether sporadic or epidemic, were indubitable evidences that there had existed in the community—or had been brought into it—antecedent cases of the same disease.

In the eighties of the last century it was still held with respect to certain diseases— notably cholera and typhoid—that the virus, although present in the dejecta of the patient, causes disease only after secondary decomposition in a suitable organic soil. So recently as 1873, Sir Charles Murchison said of typhoid fever—to which he had given the name *pythogenic* (filth born) *fever*—"it may be generated independently of a previous case by fermentation of faecal and perhaps other forms of organic matter." This view has gone by the board and the doctrine that disease is born in filth remains with us merely as the umbilical stalk to account for the inheritance by the modern health officer of the burden of back-yard sanitation.

At the same time when the pythogenic theory was accepted it was also held that with respect to such diseases as smallpox the sick patient himself—not his dejecta—is the nidus of infection and that personal contact, or, as we sometimes say, contagion, is the principal if not the sole pathway of infection and transmission from person to person. Consequential to such a view there was developed the technique of isolating the sick and holding them in quarantine for such a time as was described by the period of infectivity for the disease. Even up to a decade ago it was tacitly accepted that the contagious diseases could be completely stamped out if only all persons sick with them could be isolated in strict quarantine. In a modified sense we still adhere to such a belief with respect to a few diseases. But for the most we now know that the communicable diseases can not be controlled either in their usual (endemic) or in their epidemic forms through this means alone.

The appearance in 1903 of Robert Koch's "Die Bekämpfung des Typhus"[8] following his study of typhoid at Trier marked the beginning of a new era in epidemiological thought. He demonstrated that persons themselves healthy, particularly persons who had previously survived an attack of the disease, may be carrying and continuously or intermittently excreting typhoid bacilli virulent for others. And the appearance in the United States in 1910 of Dr. Charles V. Chapin's book, "The Source and Modes of Infection," marks the beginning of modern concurrent epidemiology, the process of ferreting out by a slow and plodding process, one by one, the individual persons whose infections threaten families or small groups. Quoting the pregnant paragraph which opens the second chapter:

> That there are occasionally seen mild cases of the infectious diseases difficult or impossible to recognize has long been known. That such cases are rare has always been generally believed. That the germs of disease can maintain themselves and increase in number in a person without causing any symptoms at all was until recently scarcely thought possible, and the idea that such latent infections are extremely common would have been scouted as preposterous. Even to-day the facts are denied by many sanitary officials, and there are comparatively few who recognize the frequency with which mild atypical forms of disease and healthy "carriers" of germs are found, or realize the tremendous importance which such cases have in the spread of the contagious diseases. Undoubtedly the most fruitful medical discovery of the last century, and perhaps of all time, was the discovery of the parasitic nature of the infectious diseases. Probably the most important discovery bearing on preventive medicine since the demonstration of the bacterial origin of disease is that

[8] Read before Der Kaiser Wilhelm Akademie, November 28, 1902.

disease germs frequently invade the body without causing disease. . . . The term "carrier" is applied to those persons in whom pathogenic micro-organisms exist, but who, nevertheless, show no symptoms. Such carriers are rarely found by the health officer, and the very mild cases also naturally escape notice and are hence called by the English "missed cases," *i.e.*, cases which fail of recognition.

For such diseases as scarlet fever or smallpox there is but little evidence to warrant the belief that carriers ever or frequently occur, although cases sufficiently mild to escape detection are common in both. Isolation and quarantine of the sick and of persons who have been in contact with them proved successful in the limited control of these two diseases, although the etiological agents were unknown.[4]

On the other hand, for diphtheria and typhoid fever, to choose only two examples from a long list, it is clearly established that healthy carriers of potentially virulent organisms are not unusual. Thus it has been found in various studies that virulent diphtheria bacilli can be isolated from the throats of 0.1 to 1.5 per cent. of healthy persons chosen at random and in much larger proportion among persons who have been in intimate contact with diphtheria patients. It is also known that from three to ten persons harbor non-virulent diphtheria bacilli for each carrier of virulent organisms.[5] With respect to typhoid fever it is clearly established that approximately one third of all convalescent cases continue to discharge typhoid bacilli for two to four weeks after the onset of the disease and smaller proportions for progressively longer periods. In the population at large it may be conservatively estimated from available data that one person in one or two thousand is a typhoid carrier. Need I stress further the significance of the carrier or his relations to the spread of infectious diseases in a population which appears to be free from sources of infection? Indeed, we have come to accept the outbreak of infectious disease in a community free from precedent frank cases as reasonably certain proof of the existence of a healthy convalescent or preclinical carrier of the virus of that disease. In *ye goode olde dayes* public health was concerned with the environment of man; modern public health is concerned with the individual. "The old sought the sources of infectious dis-

[4] Within the last few months independent investigators in Chicago and New York have published the results of researches which tend to incriminate a particular hemolytic streptococcus as the causative organism in scarlet fever.

[5] In their careful study of the incidence of diphtheria carriers in Baltimore schools, Doull and Fales (*Amer. Jour. of Hyg.*, 1923, c, 604–629) found 409 (5.25 per cent.) carriers of morphological diphtheria bacilli among 7,790 children selected at random, and 136 (1.75 per cent.) carriers of virulent diphtheria bacilli.

ease in the surroundings of man; the new finds them in man himself" (Hill). At this point we may ask the question: Why does one individual who survives an attack of typhoid fever or of diphtheria become free of the infecting organism and another remain a carrier for a longer or shorter period? Why does one person become acutely ill after the introduction of the bacilli into the body and another remain healthy although he harbors the virulent organisms and provides the pabulum for their propagation? These are riddles.

Before entering into the discussion of unsolved problems associated with specific communicable diseases it is perhaps *apropos* to indicate briefly the technique which is used in administrative epidemiology in determining when an epidemic exists.

Because of their devastating propensities and because of the dramatic characteristics which have grown up about them since their complete or partial eradication, the report of a single case of plague, cholera or leprosy is sufficient to arouse the vigorous activity of health authorities. Dysentery and typhoid do not frighten us exceedingly—we have some with us in the country the year round and are less cautious than contemptuous with them—unless there be (as we sometimes say) too much of them. Pneumonia, tuberculosis, diphtheria, scarlet fever, measles, mumps, influenza, colds and many other infectious diseases are treated with scant respect unless they recur in proportions which can not be considered within the usual safe, healthy endemic limits and take on epidemic proportions. In these instances the problem arises: Where shall we draw the border-line between endemic and epidemic frequencies? In many health departments the standard which is used in measuring the severity of reported disease is the number or rate of similar reports in the corresponding periods of the two or three preceding years. In some departments a datum known as the median endemic index is used, calculated from the reported cases of disease for the same week or month for the five or ten preceding years, excluding epidemics in the previous years' data. The uncertainty which attaches to the definition in statistical measurements of endemicity or epidemicity precludes entire impartiality in measurements of this kind. Nevertheless, it is generally possible to arrive at reasonably certain conclusions by simple statistical comparisons, whether or not a particular disease is exceeding its endemic privileges in a fright-hardened, propagandized community.

For more reasons than one we may look askance, if we will, at the all too well-accepted notion of permissible endemic prevalence of disease. The slogan of the New York Department of Health, one of the best and most wisely administered departments in the United

States—"Public health is purchasable. Within natural limitations any community can determine its own death rate"—does not overstate the case. With respect to the control of endemic disease it would probably explain itself more completely if the phrase, "within natural limitations" were expanded to "within financial and natural limitations." Assuming that a legislative body were capable of so unusual a commitment as the provision of an adequate budget, the natural limitations on the authorities would be defined only by the inadequacies of administration and of natural knowledge. We can not doubt that in such circumstances the control of epidemic as well as of endemic disease would be far more effective than it is to-day in any civilized community. Indeed, I make so bold as to say that a primary riddle is how to attain provision of adequate funds for the administration of a program of preventive epidemiology.

Let us consider briefly the prevalence of the infectious diseases, including in the category those diseases which are transmitted from person to person (with or without the intermediation of an insect, rodent or other secondary host) through the agency of "foods, fingers, fomites or flies." If we examine a list of the principal causes of death, we find that the thirteen which headed the bill of mortality for 1920 for that part of the United States for which reasonably accurate statistics are available (the Registration Area) accounted for nearly two thirds of all deaths. Further, we find that approximately 30 per cent. of the deaths are attributed to infectious diseases—pneumonia, tuberculosis, influenza, diphtheria, whooping cough, measles and typhoid and scarlet fevers; that another 30 per cent. is charged to the so-called *degenerative diseases*[6] —endocarditis and organic diseases of the heart, acute nephritis and Bright's disease, cancer and cerebral hemorrhage and apoplexy; and that all other causes of death combined make up the remaining third of the causes of mortality.

Now statistics, as the vernacular has it, are notably in poor repute. You can prove anything with them, it is said. Perhaps you can, to the gullible one, but you can't—sometimes with statistics or without—to the skeptical one. The principal cause of their shady reputation is the uncritical use of such data as I have just cited. For example, our official tables tell us that pneumonia caused 137.3 deaths per 100,000 persons in 1920 (10.5 per cent. of all deaths). Upon inspection we find that this includes "bronchopneumonia" as well as "lobar pneumonia" and "pneumonia undefined."

[6] So-called principally because their incidence is greatest in the years of advanced adult life and because they are incidental to organ failures.

Now we are inclined to believe that a very considerable proportion of cases and of deaths of lobar pneumonia are initiated as primary pneumonic infections, but we have very little ground on which to estimate the true etiology of "bronchopneumonia" or of "pneumonia undefined." At least a very considerable proportion of these cases represent pneumonia secondary to colds, influenza, bronchitis, tuberculosis, organic pulmonary, circulatory and nephritic defects, accidents and injuries and inoculative infections secondary to them. Concerning the alleged mortality rates from diphtheria, whooping cough, measles, typhoid and scarlet fevers (when combined these constituted the causes of 20 per cent. of the deaths of 1920) we can, with reasonable surety, accept them as understatements of the actual severity of these foes of humankind. It would be a bold health officer who would contend that in *his* community all the deaths caused by these acute, infectious diseases are accurately diagnosed and reported as such on the certificates of death. Concerning tuberculosis and influenza, I should like to postpone discussion of their prevalence.

Apart from the less common infectious diseases which have been omitted—notably plague, typhus, cholera, dysentery, smallpox, yellow fever, leprosy, anthrax, rabies, meningitis, tetanus, infantile paralysis, etc., and those less fatal but more widespread causes of sickness, malaria, hookworm disease, the venereal diseases and their sequelae, it must not be conceived that we have exhausted the toll of the infections of man. The evidence from pathological and from statistical studies is convincing that many deaths which are apparently caused by organic or functional defects of the heart, kidneys or other vital organs are, in a certain sense, attributable to the infections of childhood and early adult life. There is little doubt, I think, that injuries to the kidneys in non-fatal cases of scarlet fever and to the valves and muscle walls of the heart in diphtheria play significant rôles in the premature decadence and breakdown of these organs in later years of life. Furthermore, even a single remark will serve to recall that certain of the infectious diseases are important causes of morbidity but not of mortality and hence do not appear to be of significance when our attention is focussed upon tables of mortality.

It is not my plan to undertake an extensive analysis of epidemiological literature nor to run the gamut of unsolved problems from actinomycosis to zymotic diarrhea. I wish only to indicate by brief discussions the status of knowledge (and of ignorance) in a few fields which will serve as prototypes. To this end I have chosen some riddles in etiology, in the significance of telluric phenomena,

in age, sex and race factors and in the epidemiology of plague, influenza, tuberculosis and malaria.

I may recall to your minds that there are great gaps in our knowledge of etiology among the communicable diseases. We do not know or are uncertain of the causative organisms in colds, influenza, smallpox, measles, mumps, poliomyelitis (infantile paralysis), rabies (hydrophobia), typhus fever, Rocky Mountain spotted fever, foot and mouth disease, and many other important diseases. In only the most recent years in the one case and within the year in the other have the spirochetal organisms of yellow fever (*Leptospira icteroides*, Noguchi) and the hemolytic streptococcus of scarlet fever (Dick and Dick; Dochez) been described with some measure of convincing evidence.

There are equally great gaps in the study of the factors which result in the association of certain diseases as sequelae to others. Thus, for example, it is not known why bronchopneumonia is so commonly a concomitant or sequel to influenza or measles or why that curious disease, lethargic encephalitis ("sleeping sickness"), appears to follow in the wake of epidemic influenza. And, to reiterate, almost nothing is known of the factors which determine the establishment of the carrier state in typhoid fever, diphtheria, perhaps in poliomyelitis, infectious (cerebro-spinal) meningitis, pneumonia and other diseases.

The epidemiologist has been accustomed—since the rise of the bacteriological fashion—to scoff at the statements in older literature concerning the relations between epidemic prevalences and cosmic or telluric phenomena associated with sunlight, weather, rain, wind, earthquakes, ground-water level, etc. The evidences which have been coming out of the studies on the vitamin deficiency diseases, notably rickets, in recent years, have begun to teach him that he may stay to pray. If recent findings in the value of heliotherapy, especially in relation to organic and cellular physiology, as is so clearly evidenced in rickets and in surgical tuberculosis, have demonstrated anything, they have shown that sunlight plays no inconsiderable rôle in the maintenance of the normal functioning of the organism. The far-reaching effects of sunlight are reflected in the physiology of parts remote from the surface tissues. These and other environmental factors may prove to be far more significant in the elucidation of certain problems in pathology than has until recently been suspected.[7]

[7] Witness the recent studies of Colebrook, Eidinow and Hill on the effect of radiation upon the bactericidal power of the blood (*Brit. Jour. Exper. Path.*, 1924, x, 54; and of Kugelmass and McQuarrie on the photoactivity of substances curative of rickets (*Science*, 1924, *60*, 272).

The whole field of age, sex and race proclivities towards the infectious diseases reflects an unfortunate state of ignorance. Certain diseases have such characteristic age distributions that they are known as children's diseases or diseases of adults or diseases of old age. In some cases it appears that the age distribution is determined by acquired immunity. For example, a disease such as measles attacks nearly all children in a community and bestows upon them an immunity which is lasting; a large part of the adult community can not therefore "take" the infection. In diphtheria, the offspring of a mother who carries in her blood antitoxin is highly immune in the first months of life. This passively acquired immunity of the infant is soon lost, for reasons unknown, and is replaced by a high susceptibility. In later life the individual—even he who appears not to have had the disease—manifests a high immunity to diphtheria. Whether this is acquired through mild, unrecognized infections or through changes in organic structure we do not know. Many differences in relative susceptibilities between the sexes appear to be associated with secondary sex characters (differences in organic structure and function), but they are veiled in uncertainties. Differences in racial susceptibilities—I shall have occasion to refer to a few in greater detail later—are considered by some to be secondary to environmental factors, difference in diet, habits of work, play and sleep, differences in overcrowding and opportunities for infection by contact, etc.; by others they are held to be partly or largely determined by hereditary and congenital forces. When the riddles are answered we may see much that is accurate in both views. A truth, said Birrell, does not always exclude its contradictory.

The historian Gibbon tells us that:

> If a man were called upon to fix the period in the history of the world, during which the condition of the human race was most happy and prosperous, he would without hesitation name that which elapsed from the death of Domitian to the accession of Commodus [from 96 to 180 A. D.].

Upon this remark we find that Noah Webster (in his absorbing work, "A Brief History of Epidemic and Pestilential Diseases," Hartford, 1799) comments:

> It is certain that, at this time, the Roman Empire was in its glory, and governed by a series of able and virtuous princes, who made the happiness of their subjects their principal object. But the coloring to the happiness of this period is far too brilliant. The success of armies and the extent of the empire do not constitute exclusively the happiness of nations, and no historian has a title to the character of fidelity, who does not comprehend, in his general description of the state of mankind, moral and physical, as well as political evils.

What of the prevalence of disease in this most happy and prosperous period of civilization? What shall we say of the historian's judgment when we find that this choice object of historification was (as Vaughan[8] has aptly put it) "preceded by, begun in, and closed in, pestilence." Of the epidemic of 68 A. D. Tacitus tells us:

> Houses were filled with dead bodies and the streets with funerals; neither age nor sex was exempt; slaves and plebeians were suddenly taken off, amidst lamentations of their wives and children, who, while they assisted the sick or mourned the dead, were seized with the disease, and perishing, were burned on the same funeral pyre. To the Knights and senators the disease was less mortal, though these also suffered in the common calamity.

In the year 80 A. D. when, it is estimated, the population of Rome was something over a million, at the height of the epidemic, the plague carried off 10,000 persons a day. And the pest visited Rome at least six times again during Gibbon's "most happy and prosperous" period. How many times it visited various parts of Europe we can not know with certainty. The Levant and adjoining countries, situated at the gateway between the East and the West, have been plague centers for at least 3,000 years. Long before the explanation for the phenomenon was available it was known that where man travelled, there travelled the plague.

The first specific world-wide epidemic (or, as we say in the jargon of epidemiology, *pandemic*) of plague originated at Pelusium in Egypt in 542 A. D. Thence it was carried by merchants and travellers to all the then known world, carrying death in its right hand and hunger and privation in its left. Then slowly it died out; and the world was ready for the second pandemic of bubonic plague. This probably started in Mesopotamia, an old endemic center, in the eleventh century. Its spread, probably greatly assisted by the returning Crusaders, soon attained world-wide proportions and justly earned the name "Black Death." It ravaged Europe through the Middle Ages. "Towns were left empty and all trade was at an end. All feared 'the pestilence that walketh in darkness,' none knowing when their turn would come to be smitten." In 1664–65, the year of the Black Death in London, the disease claimed for its own some 70,000 persons in a population of half a million. Defoe's "A Journal of the Plague Year" vividly portrays from hearsay the life of that year (he was but a child in swaddling clothes when the events which he describes occurred). The discovery of the new route to India by way of Cape of Good Hope and the subsequent avoidance by commercial travellers of the endemic plague centers of Asia Minor resulted in the gradual cessation of the pandemic.

[8] V. C. Vaughan, "Epidemiology and Public Health," 1923.

To-day the world is in the grip of the third great pandemic of bubonic plague. It appears to have taken its origin in the town of Junnan Fu in China in 1871. It spread to Hongkong in 1894; thence to India, where in ten years it carried off six million persons. It has knocked at the doors of all the countries of the world and in only a few has it been refused admittance. In recent years it has claimed some six hundred thousand deaths per annum in India. Within the fortnight we have learned that there were reported 11,388 deaths from plague in India in the period November 11 to December 8, 1923, and 379 deaths from October 1, 1923, to January 15, 1924, in the Kalmuck region of Russia. In the United States it has established itself in four endemic centers, California, New Orleans, Texas and Florida, and has appeared in a total of 389 cases in the years 1900–1920.

Now, it is as clearly established as is anything in epidemiology that plague exists in at least three forms in man. In the *bubonic* and *septicemic* types the organisms invade the blood stream and set up pathological processes in the blood, lymph glands and various tissues from which they can not escape. Hence these forms of the disease are not, in the usual sense of the term, contagious. In the third form, rarer and more highly fatal, the *contagium vivum* invades the lungs, sets up a pneumonia and is found in virulent form in the sputum. It is highly contagious. Also, it is clearly established that plague is primarily a disease of the tarbagan and the rat (and possibly of other rodents) and only secondarily of man.[9] It is spread through the agency of the flea, an associate of both animal hosts and is caused by a small bacterium, the *Bacillus pestis*. One attack of the disease usually confers a lasting immunity. Preventive epidemiology depends chiefly upon control of the rat and the flea, somewhat upon the use of a protective vaccine and a curative serum, and in the pneumonic form of the disease upon measures of quarantine.

I have presented here at some length the outstanding characteristics of plague epidemiology more because they serve to illustrate many riddles than because plague is prevalent. Of itself, plague is not sufficiently widespread in the United States to constitute an immediate problem. But it is a threat which hovers over us. We are led to question: Whence does it come? We can not answer with certainty. It appears to be a chronic disease of rodents which on occasion becomes severe and highly fatal and gives rise to notable

[9] In the United States plague has been found in the gray rat (*Mus norvegious*), the black rat (*Mus rattus*), the white-bellied rat (*Mus alexandrinus*), in the mouse (*Mus musculus*), in one species of wood rat (Neotoma) and in a field rodent in Louisiana.

epizootics among these animals. The association of dead rats lying about the habitations of man and the outbreak of the disease in the human population is at least as old as the Book of Samuel. Dr. McCoy of the United States Public Health Service has pointed out, however, that the evidence is not convincing that the epizootic and the epidemic always run simultaneously.[10] The third great pandemic, that which is with us to-day, appears to have started in Tibet with some hunters of the marmot, a rodent which has long been known to carry the infection chronically. In the United States chronic infection with plague is widespread in the Californian ground squirrel (*Citellus beechyii*), a reservoir of death and destruction which we must hope will never be tapped.[11]

When plague first appeared in San Francisco in 1900 it was confined chiefly to the Chinese quarters. It came at a time when the relations of the rodent to the spread of the disease were unknown and when knowledge of such relations played no rôle in the combative measures employed. Yet the disease did not spread extensively among the white populations living in adjacent quarters. A few years later there was a recurrence of the disease and the whites furnished most of the victims. These anomalies have never been explained.

Why does the plague suddenly flare up in its rodent hosts? What is the nature of the parasitic specificity of the *Bacillus pestis* for the rodent and for man? How has this organism attained a high pathogenicity for man, so high that it causes the destruction of its host and thereby ends its own organic continuity? Why does it die out so long as there are rodents and men to feed upon? Why do some countries remain free from plague, their populations being apparently plague-immune.[12] Why is there a measured parallelism between plague immunity in a country and a high general average

[10] G. W. McCoy, *American Journal of Hygiene*, 1921, I, 186.

[11] The United States Public Health Service is carrying on an extensive anti-plague campaign.

[12] The flea, it appears, is not a specific but only a casual host. It was once thought that all fleas found on rats were of the same species. Hirst showed in 1913 that fleas of the species *Xenopsylla astia*, isolated in Colombia, do not readily bite man at temperatures above 80° F. He found also that of 788 fleas caught in Madras City, India, all were of the species *X. astia* and thereupon indicated a likely explanation for the relative immunity of this city from plague. Later (1922, 1923) Cragg collected nearly 25,000 fleas from all parts of India and found among them members of the species *X. astia, cheopsis* and *brasiliensis*. In plague areas *X. cheopsis* predominates; in plague-free areas, *X. astia*. His work suggests that the permanence of plague implantation in a community depends upon the species of flea which inhabits the locality. Further ecological study will perhaps explain the differences in the distribution of fleas.

atmospheric humidity? What are the factors which determine the appearance of plague in the pneumonic or the bubonic forms? Why is pneumonic plague never found in rats; why does it occur commonly in squirrels; why does it more commonly appear in man following squirrel than rat infection? These are a few problems which call for solution. That they are not unique for plague but are known in analogous forms in the epidemiology of other diseases will appear shortly.

In September, 1918, epidemic influenza appeared in malignant form on Commonwealth Pier in Boston.[13] Two months later there was scarcely a community in the United States free from it. It had spread like wild-fire through the population, numbering twenty million cases and nearly half a million deaths, a far greater toll than the war can boast. It took rich and poor, old and young, robust and feeble, male and female. In most places it was bewildering in the acuteness of its onset and the amazing rapidity of its spread, running at a pace which recalls the plague. It generally lasted some 8 to 12 weeks and tended to recur some 7 or 14 weeks later. We know that it has visited the civilized world before in pandemic form with some regularity and at least with undiminishing severity certainly since the sixteenth century. Eichel[14] has grouped the outbreaks of influenza into four epochs (1557–80; 1729–43; 1824–51; 1889–1900) and finds that the intervals between them have been diminishing (172, 95, 65 and 26 years, respectively). Epidemics of influenza in historical times can be recognized by the recorded descriptions of the acuteness of onset of the symptoms in the individual, the notable, extreme prostration and weakness unaccompanied by specific signs or symptoms sufficient to account for them, the rapid spread of the disease and by the striking characteristics—often encountered in the recorded testaments of influenza visitations in the past—that so many are acutely, painfully sick and that so few die. Indeed, it is almost safe to say that *per se* influenza never kills; death is due to secondary causes and complications, notably to bronchopneumonia.

The epidemiological study of influenza is unusually complicated by the mildness of the disease in many persons and hence the facility with which it may be spread and because the lack of clinical specificity renders early or certain diagnosis extremely difficult. The rapidity and generality with which it moves through a population argues for spread through personal contact or some other

[13] The first outbreaks in the United States appear to have occurred in certain army camps in the spring.

[14] Quarterly Publication of the American Statistical Association, December, 1922, pp. 446–454.

common medium. The uncertainty which attaches to its true etiology renders more specific information difficult of attainment. A number and variety of micro-organisms and filterable viruses have been incriminated, but none holds an unequivocal claim to a causative relationship. Recurrences of epidemic influenza in the winters subsequent to that of 1918–19 have provided some meager opportunities for the further study of the disease; but comparatively little has been discovered. The etiology of epidemic influenza remains a riddle.

We may turn our attention for a moment to the alleged origin of epidemic influenza in endemic or inter-epidemic influenza. A malady "influenza" reported on death certificates is well known, year in, year out. In "normal" years it is reported as the cause of more deaths than typhoid fever or diphtheria. Opinion is at variance, however, as to its precise relation to the disease, "epidemic influenza." There can be little doubt that in inter-epidemic years the name "influenza" is used to describe various acute catarrhal and bronchial inflammatory conditions, the name being a hang-over from previous epidemic years. It has usually appeared that as the time after a great pandemic lengthens, the name is used less and less until it comes to be unknown to a considerable part of the lay or medical population; it remains only as "a mere tradition in medical nomenclature." Professor Jordan[15] quotes Mrs. Carlyle to the effect that:

> Medical men all over the world have merely entered into a tacit agreement to call all sorts of maladies people are liable to, in cold weather, by one name, so that one sort of treatment may serve for all, and their practice be thereby greatly simplified.

And one is tempted to agree that therein lies more truth than jest. I can not enter into a detailed discussion of the arguments which have been adduced by numerous writers, pro and con, on the identity of epidemic and inter-epidemic influenza. It must suffice to indicate that opinion is at variance and the problem is still with us awaiting further evidence and more careful study. In certain respects epidemic influenza appears to differ from its inter-epidemic namesake. Thus the epidemic disease occurs chiefly in young adults; the inter-epidemic disease in the very young and old. The negro is less or the white man more susceptible to epidemic than to inter-epidemic influenza. The influenza epidemic of 1918 is also sharply marked off from the endemic influenza of preceding years

[15] Jordan, E. O., "Inter-epidemic influenza," *American Journal of Hygiene*, 1922, II, 325–345.

by a higher mortality among white males than among white females and by a relatively increased mortality in colored males by comparison to colored females.[16] Also, it appears—so far as data are available to test it—that the findings from the vital statistics of the 1918–19 epidemic agree with those from the 1889–92 epidemic in those respects in which they differ from the findings on inter-epidemic influenza. It is recognized, of course, that the difference may be due to deaths which are attributable to other causes but which are ascribed to influenza in inter-epidemic years and confuse its true statistical characteristics.

To those students of epidemiology who consider epidemic and endemic influenza the same disease, the chief problem at issue resolves itself in the search for an explanation of the remarkable change in the invasiveness and malignancy of the infecting organism or of changes in the factors of immunity in the host which will account for the apparent differences between the diseases. To those who adhere to the view that "endemic influenza" is a misnomer and bears no close relationships to "epidemic influenza" the riddles which remain unanswered are: Does epidemic influenza maintain a thread of continuity from epidemic to epidemic? Why does the disease sometimes take on epidemic proportions? Why does the epidemic die out? Or does it arise suddenly, spontaneously, *de novo?* It is almost gratuitous to add that the answers can not be given.

Shortly after the outbreak of influenza it became evident that in some cities the fatality of the disease was far greater than in others. The statistical data on mortality from influenza have been studied very thoroughly in attempts to ascertain the causes for the observed variations among communities. It was discovered by Raymond Pearl and confirmed by Winslow and his associates[17] that there is a high statistical correlation between the explosiveness of the outbreak and the normal death-rate from pulmonary tuberculosis, organic diseases of the heart, organic diseases of the kidney or of the normal death-rate from all causes of death in years preceding that of the epidemic. This correlation—the tendency of a community to have a high death-rate in otherwise normal years and to have suffered severely from epidemic influenza—remains an inter-

[16] L. K. Frankel and L. I. Dublin, *American Journal of Public Health,* 1919, *9,* 731–742; J. D. Craig and L. I. Dublin, *Transactions of the Actuarial Society of America,* 1920, *20,* p. 134; E. O. Jordan, *loc. cit.*

[17] R. Pearl, *Public Health Reports,* 1919, *34,* 1743–1783; C.-E. A. Winslow and J. F. Rogers, *Journal of Infectious Diseases,* 1919, *26,* 185–216; R. Pearl, *Public Health Rep.,* 1921, *36,* 273–298; C.-E. A. Winslow and C. C. Grove, *American Journal of Hygiene,* 1922, *2,* 240–245.

esting discovery. What does it mean? That the observed relationship, measured in statistical terms, is real can not be questioned. It must be remembered, however, that the relation between two groups of statistical data may be one of very high correlation and yet need not be direct. Indeed, it may be very remote. In the present instance the high correlation does not necessarily mean that *because* in a given community the normal death-rate from certain organic degenerations was high, influenza was severe. That may have been the case. It is equally possible, however, that some common factor (*i e.*, differences in proportions of persons of different nativities, or the presence in the population of a particular community of micro-organisms of especial virulence) may be found accountable for both. Recently, Professor Huntington[18] has discovered that there is a significant statistical correlation between the death-rate from influenza and pneumonia and the weather. He thinks it suggests that "the favorable conditions of the air were the greatest factor yet detected in helping the people of the United States to ward off the influenza in the fall of 1918." If one recalls, however, that this is argument *pro hoc, ergo propter hoc* his conclusion must be accepted with caution. These statistical discoveries have added two more significant riddles to our already long list in epidemiology.

I wish that it were possible to discuss here in greater detail the problems associated with the alleged periodicity of influenza and to tell you of Dr. Brownlee's statistical machine, the Juggernaut "periodogram" which, built out of the statistics of epidemics which have passed, marches on into the future and ventures crushing predictions of epidemic returns. But I may only mention it in passing and indicate that with influenza as with certain other diseases a sort of regularity appears in the intervals between successive epidemic waves. Accepting the fact, it is uncertain whether the explanation is to be sought in factors of temporary immunity following infection, in telluric relations or in cyclical variations in the virulence of the infecting organisms.

Of all the infectious diseases, tuberculosis is the commonest in occurrence and the most wide-spread. In the United States alone, it is estimated that 160,000 persons die each year from this one disease.[19] And in certain other countries, for example, in Germany and France, the mortality is even higher. It may be estimated that of the 110 million people living in this country, nearly ten million (something fewer than one in each ten) are doomed

[18] E. Huntington, SCIENTIFIC MONTHLY, 1923, *17*, 462.

[19] Estimated on the basis of 1.5 deaths per 1.0 reported death.

to die from this dread "white plague" unless its onslaught is checked. When this appalling loss is considered in light of the fact that tuberculosis falls especially during the period of the individual's greatest usefulness—75 per cent. of the deaths occurring between the ages of fifteen and sixty—and when premature death brings the greatest burdens upon the families of the deceased, the tremendous importance of anti-tuberculosis measures and campaigns can be fully recognized. During the past fifty years the mortality from tuberculosis has been declining rather steadily. However, modern methods of control have so far made but little apparent impression upon the gross amount of infection. The social and economic conditions of the mass of the population are related in a peculiarly pertinent manner to the determination whether an individual will go through life with healed tuberculous lesions or will succumb with clinical tuberculosis. The usual methods of preventive epidemiology are, in a considerable measure, inapplicable to tuberculosis control. The present-day campaign against the disease is largely dependent upon attempts to change certain social and economic relations and personal habits of living.

For the purpose of our discussion we may consider that in civilized communities tuberculosis occurs in two forms: (1) an acute febrile disease, observed principally among children, and bearing the stamps of the infectious maladies such as typhoid fever and diphtheria; and (2) a chronic disease, often years in duration, most commonly pulmonary in localization and particularly associated with the years of young adult life. From the findings at autopsy upon persons who have died from causes of death other than those associated with the germ of tuberculosis and from the so-called von Pirquet test (the application of extracts of the bacillus of tuberculosis to the abraded skin) it has become clear that among civilized peoples nearly every individual who has attained the years of adult life—if not actively sick with tuberculosis—harbors the latent infection.

Among primitive peoples, on the other hand, the von Pirquet tests are negative before tuberculosis is introduced among them by their civilized deliverers from the ways of barbarism; and the disease, when first introduced, runs the course of the infectious type and is not partial to any particular age group. It kills rapidly and indiscriminately. Robert Louis Stevenson tells us:[20]

> The Marquesan race is perhaps the handsomest extant. Six feet is about the middle height of males; they are strongly muscled, free from fat, swift in action, graceful in repose. To judge by the eye, there is no race more

[20] "In the South Seas," p. 38.

viable; and yet death reaps them with both hands. When Bishop Dordillon first came to Tai-o-hae, he reckoned the inhabitants at many thousands; he was but newly dead, and in the same bay Stanislao Moanatini counted on his fingers eight residual natives. The tribe of Hapaa is said to have numbered some four hundred, when the smallpox came and reduced them by one fourth. Six months later a woman developed tubercular consumption; the disease spread like a fire about the valley, and in less than a year two survivors, a man and a woman, fled from that new-created solitude. . . .

According to Calmette, an English speculator introduced into Lima two thousand natives of the Marquesas. In less than eighteen months three fourths of them were dead of tuberculosis. In Queensland—something of a resort for tuberculous Englishmen—the Polynesians constitute but 2 per cent. of the population and furnish 22 per cent. of the deaths from tuberculosis.[21] When first becoming acclimated to life with the white man the African negro shows the same high susceptibility to acute infectious tuberculosis. Similarly, among the American Indians high death-rates from tuberculosis suggest the maintenance of a primitive susceptibility.[22] Following dissemination of the disease among these peoples there appears among the survivors a heightened resistance to the disease. It appears, then, that the susceptibility of the civilized man's child partakes of the character of that of the primitive man. The *comparatively* lesser frequency of acute tuberculosis among these children (only a small proportion of them succumb to it) argues, however, that *tuberculization* of a population results in the acquisition by the newborn of a distinct, if partial, immunity—an immunity sufficient to prevent the tuberculous infection of childhood from taking on an acute form in all but a few children if it is insufficient to exterminate the microbes which they have come to harbor. (It is believed that the organisms are walled off in the lungs, lymph glands or other organs in childhood and provide the nidus for an autoinfection which we recognize in later life as chronic tuberculosis.) How comes the white man's child by this relative immunity? Is it inherited or is it passively transmitted in foetal life from the tuberculized mother? We do not know.

Carefully conducted surveys in representative communities have demonstrated that nearly 1 per cent. of the persons examined were suffering from active tuberculosis, while somewhat over 1 per cent.

[21] G. E. Bushnell, "A Study in the Epidemiology of Tuberculosis," 1920, p. 60.

[22] Tuberculosis is not unique in these respects. Primitive peoples have shown extreme susceptibility to measles. The same phenomenon on a less striking scale is suggested by recent experiences in army camps. Among recruits from rural areas measles incidence was higher than among recruits from the cities.

more were arrested or partially healed cases. Thus a total of some 2 per cent. of our population may be considered tuberculous. How do they acquire the infection? Available evidence is convincing that part of it—a small part—is acquired through the ingestion of infected meat or milk from tuberculous cattle. For the rest, it is believed that the infection gains entry in early life from direct contact with the persons of the tuberculous or with objects in the environment which they have infected. Do the invading organisms gain entrance through the digestive tract following ingestion or through the respiratory tract following inhalation or directly through the circulating blood following penetration of mucous membranes of the nose and throat or of the epithelia of the tonsils? There is no single answer. Among those who are most competent in this field there is a sharp difference of opinion. We are persuaded by the positive evidence which has been adduced for each of these pathways of infection to believe, for the while, that they all serve. Extended researches in the future may supply us with a better basis for elucidation of this problem.

The incidence of tuberculosis mortality in the community is not evenly distributed. Thus among persons of different race stocks living side by side in New York state[23] the lowest mortality rate from tuberculosis was found among the native born of native parentage. The foreign-born and their native-born offspring agree much more closely with each other in these respects than with those who are native-born of native parentage. Yet very important differences are observed among them. Thus, males born in Ireland showed rates 3.5 times as great as native males,[24] males born in England, Scotland and Wales 1.3 times as great and males born in Russia only 0.7 times as great. There can be little doubt that these marked variations are considerably determined by economic differences; but there can be equally little doubt that they are in part determined by qualities, still largely obscure, transmitted from parent to offspring.

I have presented to you, at some length, the views which have been current among students of tuberculosis epidemiology and which were crystallized more or less independently by Bushnell[25] in the United States, Cummins[26] in England and Calmette[27] in

[23] L. I. Dublin, *American Economic Review*, 1916, *6*, No. 3; SCIENTIFIC MONTHLY, January 1922, pp. 93–103.

[24] Not necessarily of native parentage.

[25] *Op. cit.*

[26] *International Journal of Public Health*, 1920, *1*, 137–171.

[27] L'Infection bacillaire et la Tuberculose chez l'homme et chez les animaux. Translation by W. B. Soper and G. H. Smith, Baltimore, 1923.

France. Their work had led us to believe that the relatively chronic nature of tuberculosis among civilized peoples is due principally to the immunity acquired by the individual after occult infection in childhood. So long as we accepted the studies which showed that nearly every one who had attained adult age was thus infected and protected it had seemed reasonable to hold that wide-spread, mild infection in the early years of life was highly desirable. Indeed some of the leading scholars[28] in this field advocated the artificial infection of young children with suitably prepared doses of non-virulent tubercle bacilli as a preventive against the dangers of chance infections with virulent strains which are so promiscuously distributed by careless or unwitting consumptives. In the light of information which has become available during the past few months we are compelled to reexamine these tenets. We are now informed that skin tests for tuberculosis made in St. Louis, New York and Philadelphia indicate that at the age of 15 less than half of our children are infected as compared with four fifths for children in French, Swiss and Italian cities and more than nine tenths for Vienna.[29] The decline in the proportion of positive skin reactors among American children, when coupled with the significant fall in the death-rate from tuberculosis in recent years, compels us to ask the questions: Was the extensive latent infection of children the cause or the result of the wide-spread infection of the adult population with chronic tuberculosis? In the future shall we look with fear or with favor upon declining childhood infection? The nature of the anti-tuberculosis program will depend largely upon the answers we accept.

Though it may be paradoxical, it is true, I think, that there is no necessary parallelism between the extensiveness or completeness of knowledge concerning a communicable disease and the effectiveness of its control. Acceptance of the empirically established principle "cleanliness is next to godliness" resulted in the essential elimination from large areas in the civilized world of several epidemic diseases. Some of these, like typhus fever, have reappeared in Europe since war-time disruptions made abidance by either cleanliness or godliness highly inconvenient. If one considers the history of smallpox and recalls its one-time scourging dissemination, he is impressed by the comparative effectiveness with which the disease has been controlled despite our ignorance concerning the nature of the causative organism. This lack of infor-

[28] Vide Calmette, *loc. cit.*

[29] N. Y. Tuberculosis Association Bulletin, March–April, 1923; Barchetti, Archiv. f. Kinderheilk., 1922, *71*, 180.

mation has not appreciably interfered with the program of prevention and elimination by vaccination.

It is significant, perhaps, to draw an example contrariwise. Recall that we are in possession of a more complete armamentarium against malaria than against any other important communicable disease. Yet it remains one of the most wide-spread of all. We have perhaps more exact knowledge and are bothered by fewer important riddles in malaria epidemiology and yet it counts its victims by the millions. The following pertinent indictment I cite from the late Sir William Osler's brilliant summary "The Evolution of Modern Medicine":[30]

> It is difficult to draw comparisons in pathology; but I think, if a census were taken among the world's workers on disease, the judgment to be based on the damage to health and direct mortality, the votes would be given to malaria as the greatest single destroyer of the human race. Cholera kills its thousands, plague, in its bad years, its hundreds of thousands, yellow fever, hookworm disease, pneumonia, tuberculosis, are all terribly destructive, some only in the tropics, others in more temperate regions: but malaria is to-day, as it ever was, a disease to which the word pandemic is specially applicable. In this country and in Europe, its ravages have lessened enormously during the past century, but in the tropics it is everywhere and always present, the greatest single foe of the white man, and at times and places it assumes the proportions of a terrible epidemic. In one district of India alone, during the last four months of 1908, one quarter of the total population suffered from the disease and there were 400,000 deaths—practically all from malaria. To-day the control of this terrible scourge is in our hands. . . .

It may be estimated that we have to-day several million active cases of malaria in our southern states; and there probably are many more malaria carriers than cases. Last month the Health Section of the League of Nations reported that during the first 10 months of 1923 some 4,900,000 cases of malaria were reported in Russia, as compared with some 2,900,000 in 1922. It is also stated that the reported number of cases is probably less than half of the actual number, as only the most severe cases are seen by physicians, and the number of patients applying for treatment in the outpatient departments of hospitals at malaria stations has been restricted by the limited amount of quinine available for distribution.

Under the press of unusual circumstances and associated with the disruption of social machinery the best of epidemiological information may prove incapable of coping with an administrative problem. I would not give the impression that there are not many gaps in our knowledge of the natural history of malaria. For example, we do not know very much about the infecting organism,

[30] New Haven, 1921.

the nature of the toxic product which it produces, the explanation for the specificity between the parasite and its anopheline host, the reason for certain curious seasonal distributions of malaria or the relation between these distributions and the malignancy of the disease. Some years ago, Ross and Thomson showed that between relapses in a patient the parasites persist in the body, but where and in what stages is not known. I cite the case of malaria merely because I would urge the caution that between the availability of precise information and the effective control of an epidemic disease there are difficulties of personnel and administration which may not be minimized.

For many of the communicable diseases the education of a population through a long period of years is an essential preliminary step to an effective program of control. Witness the case of diphtheria. The large-scale production and distribution of antitoxic serum made possible a reduction in mortality, but it scarcely modified the extent of morbidity. In future decades education of the people to acceptance—nay, to demand for—the universal use of the Schick test to determine susceptibility and of toxin-antitoxin mixture to produce artificial immunity may result in the eradication of this disease.

In the domain of natural science we are grown accustomed to recognize much that is unknown: but we do not readily conceive of anything that is not knowable. The riddles in epidemiology which have received such cursory exposition here we must accept only as temporary gaps. The interest which they hold for us is grounded, I conceive, on the opportunities which they suggest for speculative and experimental research; but not because (as Goethe remarked of miracles and the miraculous): "Das Wunder ist des Glaubens liebstes Kind."

JAPAN IN 1923

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On our way to and from Siberia, in the summer of 1923, my wife and I had some interesting experiences in Japan, most of which were neither planned for nor anticipated. We left Yokohama on the night train, Friday, June 2. When daylight came we had left the coast region, and were going through a hilly country, and a little later a farming region, where the rice-fields were all under water, some with young rice plants, others being planted, and some being gone over preparatory to planting. Presently we came to Maibara Junction, where we had to change, and waited a considerable time. In the waiting room we saw a well-dressed Japanese gentleman, carrying with his hand baggage a dainty little cage containing living fire-flies (Lampyrid beetles), which are of course luminous at night. When our train came, we got into a second-class car, with seats running lengthwise on each side, and noticed that many of the passengers rested at full length, their heads on air pillows which they brought with them and inflated. Passing near the shore of the great Lake Biwa (the word biwa means a loquat), we entered a series of beautiful valleys, and winding through the mountains, in due course reached the seaport Tsuruga, from which we were to sail for Vladivostock. Taking rikishas down to the wharf, we found our ship, the *Hozan Maru,*[1] with steam up and almost ready to go.

So far, the Siberian Expedition had encountered no serious difficulties, but here our troubles began. The people at the local Osaka Shosen Kaisha (steamship) office looked us over, and examined our return tickets, and declared that they did not recognize the signature. We had purchased the tickets at Cook's in Yokohama, after a visit to the O. S. K. office in that city. There was indeed the difficulty that our passport was without visa for Russian territory (none being obtainable in the United States or Japan), but we had other papers which we supposed satisfactory, and which in fact proved quite adequate when we finally reached Vladivostock. Not only did the Tsuruga steamship office refuse to honor our tickets, even after much argument, but we were subjected to a very thorough cross-examination by the chief of police, whom we came

[1] Hozan means high or fine, perhaps to be compared with hosanna in the Hebrew scriptures. Maru is steamship.

to know later as our very good friend, Mr. Tsuji. Long after, we were informed that the office at Tsuruga suspected that our papers did not truly describe our intentions, and that we were in fact Russians in disguise going over to plot in some way against the Soviet Government! My beard doubtless lent support to this hypothesis. Had we been such dangerous characters, the vessel might have been seized, and the captain imprisoned, so the company was taking no chances.

Thus, unexpectedly, we were halted at Tsuruga, with no chance of leaving for Siberia until the *Hosan Maru* sailed again a week later. We accordingly established ourselves in the "European" half of the small Kumagai Hotel and tried to make the best of what seemed to be our misfortune. As it turned out, nothing could have been more fortunate, for we not only made many interesting observations in natural history, but saw the real Japan, as we should not have done in a tourist resort. Tsuruga is a large seaport closely built in the usual Japanese style, with no very large or fine buildings. The inhabitants are purely Japanese, except for an occasional Russian, now dressing and living in Japanese style and evidently very poor. There is not a single American or Englishman in the whole place. The people are nearly all Buddhists, but there are about 50 Christians, who keep up a small Methodist meeting-place and a Salvation Army depot. Although English is taught in all the schools and has been for a number of years, very few can speak it, any more than our people can speak the French or Latin they have been taught. Looking for an American, we noticed near the wharf a large building inscribed Standard Oil Company of New York, and going to the office found an English-speaking Japanese, Mr. Okano, who greeted us in the most friendly manner and did much to assist us in many ways. We also became well acquainted with the police officer, Mr. Tsuji, who took us to have tea in a Buddhist temple. Our shoes removed, we sat on the soft matting, surrounded by the images and inscriptions appropriate to the place, while out of the open door we saw a typical Japanese garden, with dwarf trees and pools in which gold-fish swam. The great inscription just above us read (as we were told) "After the rain, clouds of incense arise from the flowers." We were given tea in dainty bowls, and California sun-kissed raisins. In such surroundings one wondered whether the beauty and sense of repose were a reflection of the inborn Japanese temperament or whether the religion had molded the people to its type, after centuries of devotion. It is perhaps like asking whether there were first butterflies or flowers adapted to be pollinated by them. We were taken to see the National School for girls, presided over by Mr. Otsuki. The classes visited

were one in English (taught, of course, by a Japanese), one in flower arrangement (using the iris and chrysanthemum), and one in the etiquette of serving a cup of tea. Evidently the graces of Japanese life are not left entirely to racial temperament or instinct. We also visited the playground, where the girls, in short skirts of European type, were taking vigorous exercise in a great variety of ways. The new Japan is unanimously going to school, and it is a great sight to see the streets filled with children every morning. The youngsters regarded us with interest, but always with politeness, though to them we must have had many of the qualities of a circus.

America was represented in Tsuruga by the "movies." We went to the cinema theater one evening, and saw the comic adventures of a policeman in Chinatown, San Francisco, and another American play showing all sorts of extravagant adventures connected with the "evil eye," evidently made on the coast of California. After these absurdities came a Japanese play, which so far as we could see was of a dignified character. Two interpreters or speakers followed the pictures with dialogue and explanations, one to give the male, the other (in squeaky tones) the female voice. We felt very indignant that American life should be so misrepresented abroad and thought that some concerted effort should be made in this country to send worthy and characteristic films to Japan and elsewhere. Apparently the purely commercial interests can not be trusted in these matters, and thus great opportunities are lost and great harm is done.

The narrow streets are solidly lined with low wooden houses, open in front, and with nearly always something offered for sale. Entering these little shops, one is not pressed to buy and sometimes it is difficult to find the owner. It would seem easy for passers-by to take the goods, but there is no pilfering. Swallows build their nests under the eaves or on the rafters, flying in and out continually. No doubt they aid greatly in keeping down the mosquitoes, and we found these insects comparatively scarce, in great contrast with conditions on the Kudia River in Siberia. The species at Tsuruga, determined by Dr. Dyar, proved to be the ordinary form of Europe, *Culex pipiens* Linnaeus. In these Japanese towns, there is constant danger of fire, and we heard it said that the average life of a house in some places was not over seven years. At one o'clock one night we were wakened by a great turmoil and hastily dressing went out in the street. There was a red glare in the sky, and every one seemed to be up and running toward the fire. We followed the crowd and found buildings blazing close to the girls' school. The fire-fighting arrangements

were primitive, but the great number of men engaged and the close proximity of water made it possible to subdue the flames, which we feared at first might destroy the whole town. The crowds were kindly, and we felt perfectly safe in their midst.

Tsuruga not only has its temples and temple gardens, but also a fine park. At the entrance to the park is a notice in English and Japanese, the former as follows:

NOTICE

The following actions are strictly forbidden:

I. To shoot or catch birds or beasts.

II. To burn fire or amuse with fire-works or make any other dangerous tricks.

III. To do any kind of business without permission.

IV. To draw a cart of any description through the park, except the road, public or private.

V. To cut or remove trees or shrubs.

VI. To harm the landscape of the park.

A very noticeable feature was the large number of book-stores, and in one of them we saw a picture of Darwin prominently displayed.

Taking a walk in the vicinity of the town, I was much pleased to find on a mulberry tree quantities of the extraordinary scale-insect, *Takahashia japonica,* which I described in 1896. It resembles our cottony-scale of the maple, but the white ovisac becomes greatly lengthened, and the shrivelled female is left suspended at its free end. I found that the insect was very well known to Mr. Toyoda, of the Plant Quarantine Station at Tsuruga, where I saw a collection of Coccids and a good entomological library. In general, I found scale-insects scarce at Tsuruga, contrary to expectation. Scanty material of a possibly new *Phenacaspis* occurred on a native plant, and the beautiful *Orthezia japonica* of Kuwana was common on low herbage by the roadside.

Going north from the town, we passed through a large tunnel and came out near the quarries where limestone rock is obtained and used in the manufacture of lime. The road runs close to the shore of the bay and is cut in the side of steep forested slopes, which are covered with the most beautiful trees and shrubs. The aspect of the flora is almost semitropical, very different from the strictly temperate (Palearctic) flora of the Maritime province of Siberia. A very fine tree, with somewhat the aspect of a basswood, was in full flower, and attracting vast numbers of humble-bees, the humming of which could be heard for some distance. The tree was

determined for us by Mr. Rehder as the Rhamnaceous *Hovenia dulcis* of Thunberg, the original describer evidently having noted its fragrance. It is the only species of its genus, so far as I can learn, but extends as far as the Himalayan Region. The commonest of the humble-bees was the *Bombus diversus* of Smith, but there were several other species, including the one I described several years ago as *Bombus sapporoensis*. This latter, marked with yellow, black and red on the abdomen, was extraordinarily "mimicked" by a Syrphid fly of the genus *Mallota,* found at the same place. This was the more surprising because these flies do not, so far as we know, have any biological relation with *Bombus*. This *Mallota,* a large and handsome species, proves to be new to the U. S. National Museum, but it can not be identified because no copy of Matsumura's great work on the insects of Japan, in which it is probably described, is available. I tried to procure a copy, but the whole reserve stock was destroyed at the time of the earthquake.

Bees were not as numerous at Tsuruga as I expected, although there were many flowers. The only new species obtained was a leaf-cutting bee (*Megachile*). We were pleased to find the males of the great carpenter bee flying round in circles. F. Smith, of the British Museum, long ago described it as *Xylocopa circumvolans,* although he said nothing about the habit which might have suggested the name. Near the tunnel we found the so-called Japanese beetle, *Popillia japonica* of Newman, which has become such a pest in New Jersey, but seems quite harmless in its native home. We had met Messrs. Clausen and King in Yokohama, where they were stationed for the purpose of investigating this insect for the U. S. Government and determining its natural enemies. In this undertaking they have been very successful, as will appear in the course of time. On the coast of Siberia we also found *Popillia,* very like the Japanese form, but a different species.

Various butterflies were noted, especially some very large and handsome species of *Papilio* (swallowtail), having quite a tropical aspect. At the same time, we noted a form of the "small copper," *Chrysophanus phlaeus,* a species which we took a few years ago at the other end of the Palearctic Region, in Madeira. The particular form of the copper butterfly occurring in Japan has just (1924) been named *japonica* by Edmund B. Ford.

Particularly interesting to me were the snails of the region near the limestone quarries. The great Helices, generally referred to *Eulota* (subgenus *Euhadra*), were represented by three forms, one of which I have since described as new. These mollusca have a broad dark stripe down the back of the animal, and the internal anatomy is so different from that of true *Eulota* (which we found

in Siberia) that I consider *Euhadra* of Pilsbry a valid genus. Another very attractive snail was the fusiform sinistral *Clausilia japonica nipponensis* of Kobelt, which I found in some numbers on the face of a rock. Although much work has been done on the rich snail-fauna of Japan, there is still much to do, especially in studying the distribution, habits and anatomy. It would be a good idea to explore the coasts and islands by means of a large boat, in which it would be possible to sleep and cook. The many sheltered harbors afford ample protection from rough weather. It must be said of the snails at Tsuruga that they have an Oriental, not Palearctic aspect, totally different from the snail-fauna of the Siberian coast.

We collected only a few plants, for the names of which we are indebted to Messrs. Maxon (ferns), Killip, Rehder and Nakai. A brief account of them will serve to convey some idea of the flora:

Apocynaceae. *Trachelospermum asiaticum* Nakai, closely related to the fragrant cultivated Star Jasmine, which comes from China. The leaves of *T. asiaticum* vary greatly, from lanceolate to subovate, even on the same twig. If fossilized, they would probably be referred to two species.

Campanulaceae. *Campanula punctata* of Lamarck, a fine large "bluebell" with whitish, finely spotted flowers, when well developed more than an inch and a half long. We observed the same species again in the coast region of Siberia.

Hypericaceae. *Hypericum patulum* Thunberg, a large St. John's Wort, with opposite leaves and yellow flowers.

Leguminosae. *Indigofera pseudotinctoria* Matsumura, a close relative of the well-known Indigo plant. It has small pinnate leaves.

Saururaceae. *Houttuynia cordata* Thunberg, with cordate leaves having long slender tips. This is closely related to the American (California to Rocky Mountain region) *Anemopsis*, these plants being isolated remnants of a group which was doubtless once much better developed.

Rhamnaceae. *Hovenia*, mentioned above.

Saxifragaceae. *Deutzia scabra* Thunberg, a beautiful shrub well-known in cultivation, but here in its native habitat. The genus has a number of species in Asia and one in Mexico; we should accordingly expect to find it fossil in the United States, but so far it has not been recognized.

Verbenaceae. *Callicarpa japonica* Thunberg, with small flowers, and large broad leaves with long slender tips, suggesting the "drip-tips" of so many plants in the moist tropics.

Vitaceae. *Parthenocissus tricuspidata* Planchon, closely related to the Virginia Creeper, and having very broad leaflets.

The ferns were extremely fine and varied; a few that I collected proved to be *Asplenium trichomanes* Linnaeus (also common in America), *A. incisum* Thunberg, *Adiantum pedatum* Linnaeus, *Cyrtomium falcatum* (Linnaeus, filius), *Polystichum* sp., *Pteris* sp., *Onychium japonicum* (Thunberg), *Dryopteris varia* (Linnaeus) and *Coniogramme japonica* (Thunberg).

By the end of the week, thanks to Mr. Clausen and other friends in Yokohama, our difficulties with the shipping company had been overcome, and with much politeness they offered us the best cabin on the boat. We were seen off by a delegation of Japanese, bringing presents, and departed with a very warm feeling for the Japanese in our hearts. We hear it said that the Japanese do not like Americans, but no people could have been more friendly than the citizens of Tsuruga. We had been isolated in a purely Japanese town, and had every opportunity to notice signs of dislike or hostility, but found none. Should we behave as well to a couple of Japanese coming unexpectedly among us, with no special recommendations?

It was not until the end of August that we returned from Siberia. We were met by our friends Okano, Tsuji and others, and had the pleasure of presenting to Mr. Tsuji a fossil plant (*Sequoia*) from Siberia—the first fossil he had ever seen. He begged for a second specimen, to place in the museum of the girls' school. The evening of that day Mr. Tsuji appeared with a roll of cloth under his arm. "This," he said to me, "will be your kimono; my wife and daughter will sit up all night to make it for you, and I will bring it to the train." So it was, for although the train went at about seven in the morning, and the station was about a mile from the center of the town, Mr. Tsuji and other friends were there to see us off. The kimono was worn with pleasure and comfort in Yokohama, but eventually went to a refugee after the earthquake.

On our way back we made an excursion to Kyoto, and then visited the fine university and were shown over the extensive biological laboratories. We noticed all the standard European and American biological journals on the table in the library. Leaving Kyoto for Yokohama, we stopped off at Gifu to see the famous old entomologist Mr. Nawa and visit his museum. We had telegraphed that we were coming, and were met by a young entomologist, a specialist in Coleoptera, who however knew hardly any English. After a very long ride on the crowded street-car we reached Mr. Nawa's home, to find that he was confined to his couch and unable to work. He welcomed us very kindly, and gave us a copy of the volume issued in his honor; but as he spoke no English, and no interpreter could be found, it was impossible to converse. In the museum we saw many interesting things, especially a series of well-preserved fossil insects of Tertiary age, which unfortunately have never been described.

Leaving Gifu late at night, we found it impossible to procure berths in the sleeper, and had to rest as best we could on the long seats of a second-class car. Reaching Yokohama next morning, we

proceeded to the home of Mr. Charles Bishop, at 222 A Bluff, where we had the good fortune to stay for several days. Mr. Bishop is a Methodist missionary who has been in Japan over forty years, and from him we learned a great deal about the country. Guided by him, we visited the Imperial University and Methodist College in Tokyo, only a couple of days before their destruction. We took passage on the *Empress of Australia,* to sail punctually at noon on September 1. I had taken our boxes, containing the Siberian collections, to the ship the day before. On the morning of September first we accordingly took rikishas down to the wharf, and looked up our cabin, leaving our hand baggage. There was already a stiff wind, and I recalled afterwards that my rikisha man's hat blew off as we crossed the canal, and narrowly escaped falling into the water. Everything being arranged, we went back into the city to see some of our friends, particularly Mr. P. E. Jenks, the admirably efficient U. S. vice-consul, and to spend the last of our Japanese money. As we went in and out of the well-known stores and purchased dainty and beautiful things, we little imagined that of all we saw before us, only what we took away would be saved from utter destruction! Had the earthquake occurred an hour sooner, we should have been in the thickest part of town, with every probability of losing our lives. Returning to the ship, which lay alongside the wharf, we stood on the deck watching the crowd which had come to say good-bye. Every one who did not belong on board had been ordered off, and following the picturesque Japanese custom, those on the wharf held paper streamers of all colors, the other ends of which were in the hands of their friends aboard. As the boat pulls out, the friends on shore run along the wharf, until at last the ribbon-like paper breaks, and that is final adieu. It was three minutes to noon, when without the slightest warning, the great ship was violently shaken, as though some explosion had occurred in her interior. Some one said "earthquake," and when we looked down, we saw that both ends of the wharf had collapsed, though fortunately the part on which most of the people stood was still intact. Looking toward the city, we did not at first appreciate the magnitude of the disaster. Large buildings still apparently stood; we could not see that their roofs and floors had utterly collapsed. Almost immediately there were great clouds of dust, and then smoke and flames, obscuring the view. The *Empress* made no attempt to start on her voyage, and in fact her propeller had got tangled up in the anchor chains of a steamer just behind, and she was disabled. The wind, which we had already noticed in the morning, now increased in violence, blowing off-shore. Consequently smoke and sparks were blown all over the vessels in the harbor, and it was only through

the industry of the crews in playing water over them that they were kept from burning. Fortunately, the *Empress* had new hose-pipes, in the best of condition. The earthquake having come just at the hour when people were cooking the noon meal, fires started everywhere as the wooden houses collapsed, so that before long the whole place was like a gigantic furnace. Many people caught in the wreckage and unable to extricate themselves were burned to death. One heard afterwards of heartrending cases, as that of a man whose wife was caught under a heavy timber and who had to be dragged forcibly from the approaching flames by some of his friends, while his wife perished before his eyes. Other cases ended more fortunately; thus there was a man who saw the foot of a woman sticking out from a mass of débris and got the impression that she might still be alive. So he went to work and extricated her, saving her life. They made their way toward the water-front, and what with his exhausting labors, and the sight of so many dead bodies, and the fearful heat, the man now fainted, and the woman managed to drag him to safety. Eventually they both reached a ship. The Japanese people showed the utmost fortitude and played up splendidly, excepting certain officials, who apparently could not act without orders. There were of course some criminal acts, as in all such crises, but it is better to remember rather the numerous deeds of kindness and fidelity. Thus a man described to me how the Japanese chauffeur saved his wife and child. They were in the automobile, not far from the waterfront, when the earthquake occurred. The chauffeur had a family of his own, but he seemed to think only of saving the American woman and her little child. Guiding them to the edge of the harbor, he waited for the chance of a boat. The fire increased, and at last he said, "I think you must jump in the water, with the baby, and take the chance of its being drowned." However, just then a boat appeared, and it was not until the woman and child were safe on a ship that the Japanese went off to try to find his own family. In another case, a certain man who had an office down town, was unable, on account of the fires, to make his way to the top of the Bluff, where his house, containing his wife and child, was situated. The next day he set forth again, although friends tried to dissuade him, saying that all was certainly lost and he would only risk his life for nothing. But he made the journey, and found indeed that his home was gone and his wife dead, but under a bush sat the Japanese nurse with the baby. She had been there, waiting, for 24 hours, and simply said: "I knew you would come." These cases are not rare exceptions, but rather typical of what was going on everywhere.

The most complete destruction, prior to the spread of the fire, was probably in the heavy English-built buildings along the Bund and Water Street. So far as we know, not one person came alive out of the Imperial Hotel. We saw a man whom we knew, who worked in Cook's office. He was saved, because he was in the street (in a rikisha) at the time of the quake; but he hastily made his way to the office, and found nothing but ruins, without a single survivor among those who had been within. A few (including a woman) managed to swim out to the ships, but many more entered the water, and, immersed up to their necks, waited for help. Thus some stood for hours, ducking their heads as the heat became too intense. The ships' boats were out all night rescuing people and very soon every vessel in the harbor was crowded with refugees. The park and baseball ground were full of people, who found here a place of comparative though by no means perfect safety. Estimates of the loss of life can never be exact, but it was enormous. Up on the Bluff, there were more or less isolated houses which did not burn, and fortunately one of these was that belonging to the American entomologists, who were not in town at the time. I saw Mr. Clausen later at Kobe, and he greatly feared for the safety of his valuable notes and collection of the Hymenopterous family Chalcididae, which represented a very great addition to the known Japanese fauna. It turned out that the Japanese servants had had the sagacity to hide these materials under the floor, where they escaped the looters, and so these valuable scientific materials were saved.

On September 2, the *Empress* had a very narrow escape from destruction, owing to the ignition of a large tank or barge of oil, which was in front of the Standard Oil building. The burning oil drifted rapidly toward the vessel, and it was only with difficulty that she was got out of the way in time. She was assisted by a Dutch steamer, which, as we learned later, was herself full of combustibles, and was taking big chances. In spite of this peril, there was no panic on board, though all the passengers were ordered to the side of the boat away from the oil, and sailors played water all over the other side. However, that burning mass, had it caught us, must have destroyed the vessel and all on board.

The *President Jefferson* came in from the south, and as the *Empress* was disabled, we hastily transferred to her, taking the more precious part of our collections in hand bags. The *President* put back to Kobe with a load of refugees, and to get food and water, and then started for the United States, with many more Americans than could be accommodated in the cabins. In spite of their losses, the passengers were a fairly cheerful and very sociable group and we had some of the best concerts I have ever heard on shipboard.

We were the first to arrive in America after the earthquake, and nothing could exceed the kind treatment we received, according to our needs. The Siberian collections were all saved, those left on the *Empress* coming on later, without the slightest difficulty with either the customs officials or the shipping agents. They are now for the most part in the U. S. National Museum and are in process of being described.

Japan is a land in which the old is strangely mingled with the new. May she contrive to keep her great and striking virtues, while assimilating what is best in modern science and culture. When coming out on the *Taiyo Maru*, we were charmed by a little Japanese child, Hisa Takata, and I was moved to write the following verses, which were printed on the ship and distributed to all the passengers. After having been in Japan, I do not think I can better express my feeling about the country.

PUELLA JAPONICA

I had a dream of old Japan, of ages long ago,
The glory of the sunrise land, the soft and mellow glow
Of light upon the mystic glades where dwelt the maidens fair,
The perfume of the peonies upon the summer air.

And can we then recall the past, and make it live again,
Forget the turmoil and the strife, forget the grief and pain,
And dream that all the world is young, and all the earth is gay,
As hand in hand our fellows walk along the golden way?

It is no dream, I see again the beauty of the past,
The very soul and essence of the old Japan at last,
All concentrated in a maid as tiny as may be,
And full of charms to win the hearts of all who chance to see.

And yet it is the future that the past has made for us,
The olden time will not return, but build the new, and thus
Our maiden takes her heritage, her power of mind and heart,
To help to make the new Japan, of which she is a part.

THE PHYSICAL BASIS OF DISEASE

IX. THE TREATMENT OF DISEASE

By THE RESEARCH WORKER
STANFORD UNIVERSITY

"ONE or two lumps?" asked "the wife" as they made themselves comfortable in the manufacturer's sitting room on the fifth floor of the St. Francis.

"Three," replied the research worker.

"If diagnosis is so often wrong," said the manufacturer, "treatment must often be pure humbug."

"We mustn't judge religio-therapists too harshly," said the research worker. "A diagnosis is not necessary from their point of view. To them all disease is but manifestation of divine displeasure. All disease to be treated by some form of religious observance.

"Their error in diagnosis, however, is a serious matter in judging the alleged results of their treatment. When Christian Scientists publish hundreds of alleged cancer cures, with not an authentic case of cancer among them, hundreds of alleged cures of tuberculosis with not a single authentic cure to be found by impartial investigators, it is a serious matter."

"Haven't they any real cures to their credit?" asked the wife.

"Yes. Alleged cures by religious methods have been carefully studied by impartial investigators, interested only in determining the truth. Also, by official boards composed of priests, clergymen, physicians and laymen. Authentic cures have been found. But these are all cures of subjective symptoms. Of psychical or hysterical forms of disease. Of the psychical accompaniments of organic disease. No direct curative effects in organic disease have been found. Only indirect effects through improvement in psychical condition. Courage, hope, absence of worry, focusing of interest."

"But the miraculous cures of the Bible?" insisted the wife.

"One of the miracles was the changing of water into wine. But no religious cult ever advocated the substitution of prayer and faith for the grape industry of California.

"D'you realize religio-therapy is the oldest form of medical treatment? Tried from earliest times. All religions. All conceivable forms. If religio-therapy were able to deliver the goods,

would it have been abandoned by the medical profession centuries ago?"

"Pretty hard on the Catholic church," said the manufacturer. "They teach the religious cure of disease."

"You're mistaken."

"But we're constantly up against it," insisted the manufacturer. "Large Catholic element in our Pittsburgh plant. 'Most every day Miss Harrison, our social worker, reports wives and children treated solely with holy water. Even though medical treatment is free to employees."

"The ignorant Catholic still preserves medieval superstitions. Cure of organic disease by holy symbols. This is not the belief, however, of intelligent Catholics. Nor is it part of the prescribed articles of faith. Witness the Catholic hospitals and nursing sisterhoods in all parts of the world. The Mayo Clinic.

"The illiterate Catholic, however, with his reliance on holy symbols, is a serious menace. The main cause of the high death-rate in Catholic countries. He is not, however, as serious a menace as his Protestant equivalent. The Catholic church is not in politics along medical and hygienic lines. Look at the governor of California refusing to endorse modern hygienic measures for fear of alienating the Christian Science vote. The regents of our state university denying adequate appropriations to the medical department for fear of antagonizing the Protestant religio-therapeutic bloc."

"Religio-therapy shows itself, not only in treatment by ritual and holy signs, but in treatment by material agents. The pharmacopeia of the middle ages was largely religio-therapy. Foul-smelling, evil-tasting concoctions to make the interior of the body an unpleasant dwelling place for invading demons. Heart-shaped, kidney-shaped, liver-shaped leaves, believed thus divinely marked for the cure of human disease.

"Probably the outstanding modern example of religio-therapeutic pharmacopeia is homeopathy. Rapidly disappearing. Practically extinct in most parts of the country. Homeopathy was based on the conscious or subconscious religious hunch that Divine Providence had placed on earth material agents for the cure of all human ills. That He had clearly marked these agents for man's recognition. About the only way we can conceive material agents thus marked is by their power to produce symptoms. An agent divinely marked to cure headache would thus cause headache if given in excessive doses. One set aside by Deity to cure nausea would produce vomiting.

"The early homeopathists found a number of material substances apparently confirming this hunch. Nitroglycerine, for example. One of the outstanding symptoms of nitroglycerine poisoning is intense headache. Queer as it may seem, nitroglycerine in small doses often relieves headache.

"Good evidence there's something in their belief," said the manufacturer.

"At the time homeopathy was founded, the biological action of drugs was not understood. Drugs were prescribed mainly because experience had shown their usefulness.

"The outstanding effect of nitroglycerine in experimental animals is to lower blood pressure. Headaches are of two classes—high blood pressure headaches; low blood pressure headaches. Nitroglycerine, given to a patient with high blood pressure headache, may reduce the blood pressure to normal and give relief. Given to a low blood pressure headache it still further decreases blood pressure and aggravates the symptoms. Nitroglycerine, therefore, is not a divinely marked cure for all headaches. A material agent for lowering blood pressure.

"But I know several successful homeops," said the manufacturer.

"I doubt if there is a physician of standing now practicing homeopathy as originally conceived. Most of them have adopted modern methods. Homeopathists in name only. Their schools and hospitals have practically disappeared in most parts of the country."

"Study of the biological action of nitroglycerine is typical of the experimental studies that have laid the foundation for modern therapeutics. Traditional remedies have been tested on experimental animals. Careful clinical evidence collected.

"This study has been most discouraging. Numerous time-honored drugs have been shown to be valueless except for their psychical appeal. Take sarsaparilla. A venerable remedy. Believed to have mysterious beneficial effects on nutrition. Wide reputation as a cure for syphilis. Sarsaparilla was shown by animal experiment and clinical evidence to be practically inert. It has virtually disappeared from modern medicine. Still retained, however, in folk medicine. Still the subject of profitable commercial exploitation.

"Other venerable concoctions have been shown to owe their sole virtue to some simple component, such as alkali. Ninety-eight per cent. of the traditional remedies have been thrown overboard. But two per cent. found to have biological effects, useful in the

treatment of disease. Most of the ancient remedies originated long before physicians had more than the crudest ideas of anatomy. Before the functions of organs were known. Before the microscope had revealed the structural changes in disease. It's a wonder even two per cent. of these remedies survived.

"Treatment based on knowledge of the biological action of drugs is not the simple process of our forefathers. They administered drugs largely for their alleged curative effects, active against all disease. To them, accurate diagnosis was not necessary. In contrast, modern scientific therapy necessitates an accurate determination of the biological abnormalities in the patient. Abnormalities to be corrected by therapeutic agents."

"The end of quacks," said the manufacturer.

"As soon as the public is convinced that modern science can deliver the goods. Except with cathartics, whose action is understood, belief in mysterious curative forces is almost universal. The dear old lady who during her husband's illness took daily doses of his medicines, to store up in her body curative powers for a time of need, is typical of the usual point of view. Even with people otherwise well informed.

"The contrast between modern therapy and medieval methods is well illustrated by any ancient remedy that has survived modern research. Iron, for example. Used since earliest times. Introduced solely because iron, the strongest metal, was believed to carry the spirit of strength into the body. Unlike most drugs introduced for similar reasons iron preparations were actually found to increase physical strength in an appreciable number of cases.

"Biological research has shown that iron is a necessary food. All animals, all plants. Without iron normal growth, even life is impossible. In higher animals, iron exists mainly as coloring matter in the blood. This red iron compound is the main agent for the transportation of oxygen to vital organs. In conditions of iron starvation, or in iron reduction from other causes, muscular weakness and other distressing symptoms of oxygen hunger are experienced. The administration of iron in such cases enables the body to raise its iron content to normal. The unpleasant symptoms disappear. Not a magic, strength-giving drug, correcting to all forms of human weakness. A normal food, effective only against weakness due to low iron percentage in the body. Given to normal individuals the excessive iron is not stored up in appreciable amounts. Thrown out in the excretions."

"Safely prescribed in all diseases," said the manufacturer. "A cure if you strike the right disease."

"Iron in various forms is an almost ideal drug for commercial exploitation. Scores of iron preparations have been put on the

market. Long lists of diseases the preparations are alleged to cure. Testimonies from impressed neurotics. Occasional individuals with iron-starvation miraculously restored to health. A cent's worth of iron, a pint of colored water, a penny bottle, a two-cent carton. Sold to druggist for twenty-five dollars a gross. Forty million bottles at a dollar a bottle worked off on the credulous public. Tempting profits."

"Probably think the suckers will throw away their money anyway," said the manufacturer.

"The financial side is of no consequence. What is important, however, is the resulting loss of human life and efficiency. Thousands of beginning cancers reaching an inoperable stage, while the fools take commercialized iron. Tens of thousands of cases of beginning tuberculosis. Venereal disease. Bright's disease. Heart disease."

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"Probably a better conception of scientific therapy is obtained from some new drug that has resulted from modern biological research. Adrenalin, for example. A chemical product, isolated from the adrenal glands of animals. Later successfully synthesized in the chemical laboratory.

"Adrenalin causes numerous biological reactions. The outstanding reaction is marked constriction or narrowing of the blood vessels. Applied to a cut surface it causes the blood vessels to shut so completely that hemorrhage ceases. A valuable instrument in surgery, particularly in parts of the body where control of hemorrhage is difficult by other means. Injected subcutaneously, adrenalin is absorbed by the blood. Causes narrowing of the blood vessels in all parts of the body. Thus increases blood pressure. A valuable agent in heart failure, shock and other conditions in which the blood pressure is so low as to endanger life. So spectacular are some of the results obtained with adrenalin that newspaper accounts are constantly appearing of corpses miraculously restored to life by its use. Not a drug with mysterious curative powers. A chemical agent with definite biological effects which may be used to counterbalance known biological abnormalities in disease.

"Nitroglycerine with its power of decreasing blood pressure, adrenalin with the property of increasing blood pressure are typical of the therapeutic agents of scientific medicine. Drugs have been found with which the action of many of the vital organs may be varied at will. Strychnine increasing peristaltic movements in the intestines. Morphine decreasing them. Atropine hastening the heart. Digitalis slowing it. Iodides increasing bronchial secretion.

Benzoic acid decreasing it. Caffeine increasing urinary output. Not agents with mysterious curative powers. Agents producing definite biological reactions. Intelligently used they may counteract the effects of disease, relieve symptoms. Indirectly assist the body in its efforts at readjustment and repair.

"In addition to these physiological aids, a number of direct curative agents have been found. Quinine, a toxic substance which kills all forms of animal life, can be tolerated by the human body in sufficient doses to kill the invading germs of malaria. Salvarsan tolerated in doses sufficient to free the body of syphilis. Antitoxic serum administered in sufficient amounts to neutralize poisonous products absorbed from a diphtheritic throat."

"I see that Dr. H—— has been acquitted," said the wife.

"H—— was tried solely for his criminal responsibility under present laws for failure to give antitoxic serum. Nineteen chances out of twenty the life of his diphtheria patient would have been saved by this serum. A nineteen-to-one bet that he was responsible for the death of the child. A legally qualified physician Hopelessly ignorant of modern biological science. H—— stated under oath that in his opinion serum is valueless. That the only cure for diphtheria is vinegar. Assuming this to be his honest opinion, he was not criminally liable under present laws. Not H——, but the present legal code was at the bar in this trial."

"If salvarsan frees the body from syphilis," said the manufacturer, "I should think substances might easily be found to free the body from tuberculosis."

"Tuberculosis and syphilis are quite different. The germ of syphilis is a very delicate microorganism. A few minutes drying renders a syphilitic discharge harmless. The mildest antiseptics sterilize it. In contrast, tuberculous sputum can be dried for weeks without losing its power to produce disease. Resists antiseptics that will kill human tissues. I am doubtful if tuberculosis can ever be mastered by this method. Commercialized products with alleged powers to free the body from tuberculosis, however, find ready sale."

5

"Biological research has not only given a rational basis for the use of drugs, but a rational understanding of drugless methods. Electricity, baths, exercises, massage. All studied for their physiological effects. Their value or lack of value determined."

"One of our Pittsburgh hospitals has been soliciting contributions for radium," said the manufacturer.

"If it's a high grade hospital, you can safely contribute. Probably want radium for a serious purpose, not a mere advertising stunt. In the hands of competent men radium is apparently a

valuable adjunct in the surgical treatment of cancer. Extravagant, unwarranted claims have been made for it, however. A source of danger in the hands of incompetent and unscrupulous, who substitute radium for older surgical methods. Numerous quack radium institutes. Fake radium specifies."

"Is there any scientific foundation for osteopathy?" asked the wife. "I haven't tried that yet."

"One of the outstanding superstitions of the middle ages was the belief in the curative effects of laying on of hands. Mysterious curative spirits believed transferred by this method. Reigning monarchs set aside certain days for such treatment. Miraculous cures reported. In time it was realized by the better informed that the only virtue in such treatment was its psychical appeal. The practice was discontinued.

"Belief in the efficacy of laying on of hands, however, remained with the ignorant. Sufficient for profitable exploitation. Exploitation was often clothed in pseudo-scientific terms. Alleged transference of 'animal magnetism,' 'vital electricity,' 'biological emanations.' With the growth of popular knowledge of electricity, the public no longer fell for this. Recent exploitations have based their claims on alleged curative reactions set up in the patient's own tissues. Stimulation of nerve trunks by pressure or friction. Osteopathy is but a modern survival of medieval laying on of hands. Abandoned by the medical profession centuries ago. No curative value except that of ordinary massage plus psychical appeal."

"But osteops claim they know more about nerve physiology than regular physicians," insisted the wife.

"Twenty-five years ago I was offered the professorship of physiology in the leading osteopathic school of this country. They'd obtained my name from a Chicago teacher's agency. At the time I was wholly untrained in medical subjects except a six weeks' summer course in college physiology. In their eyes this fitted me to pose as their final authority in nerve physiology. With knowledge far in advance of biologists who had spent a life-time in neurological research."

6

"Deplorable condition," said the manufacturer. "What's the answer?"

"But one remedy. Popular education. The physical basis of disease A course in elementary pathology in every high school."

"I should think a better attack would be through the churches," said the manufacturer. "From the facts you've cited any lawyer could make out a pretty good case against the churches as enemies of modern civilization."

"No physician would take that view. It's quite evident, however, that the churches have often been wrong in their conception of the relation of Deity to the human body. The Christian Deity has evidently set man the task of mastering, dominating the biological forces of the body, as He has set the task of gaining dominion over other material forces in nature.

"Above the portals of a big research institute there is engraved the following legend. South African, I believe:

> **¶ In the Year of the Great Winds, Ah-e-gish, Father of All Gods, descended upon Earth. ¶ And the People cried out: Ah-e-gish, Ah-e-gish! Help us, lest we Perish. ¶ Then spake Ah-e-gish: ¶ In the Earth, and in the Fruits of the Earth, have I placed all things Necessary. Find them and be as Gods. ¶ Thus speaking, Ah-e-gish ascended into the Heavens.**

"How about legal control?" asked the manufacturer.

"Ineffective. At least, so long as medical and hygienic matters are in the hands of political machines, reflecting the ideas of the ignorant. Not the wishes of the intelligent minority. Easily worked by charlatans. Bribed by commercial agents. If the making and enforcement of medical and hygienic laws could only be intrusted to a courageous, intelligent, non-partisan board. Economists. Hygienists."

"They'd hang California's ten thousand quacks," said the manufacturer.

"I'm not certain they'd pay much attention at first to irregular practitioners. They'd attack the more important problem. Elimination of incompetents and unscrupulous from the regular medical profession. Raise the profession to the honor and dignity the majority of its members so richly deserve.

"Do you realize a third of the regularly licensed physicians of California are incompetent? Half, in some states. The war was a great show-down for the medical profession. Thousands of legally qualified physicians. Representative men. Drawn from all parts of the country. Seventy-five per cent. of them so incompetent that they could be used only after months of additional training. Thirty-five per cent. so deficient that it was useless to attempt their training. Quietly discharged. Assigned to clerical duties.

"I'm revealing no secret. The matter was aired at the time in official bulletins. Subject of editorial comment in leading medical journals.

"Heavens!" added the research worker, glancing at his watch. "Twelve minutes to catch the last suburban express."

"I've my car at the curb," said the manufacturer. "Get you to the station in five minutes."

THE STATE OF SCIENCE IN 1924

HELIUM GAS AND ITS USES

By Professor J. C. McLENNAN, F.R.S.

Discovery of Helium

In the history of science there is no more remarkable example of the development of purely scientific research into industrial application than is afforded by helium. No element has a more romantic history and none is of greater interest to men of science or more likely to prove of practical importance. The gas was discovered on the sun twenty-seven years before it was found on the earth. It is one of the chief constituents of the great flames or prominences which are continually being spurted out by the sun to heights of tens of thousands of miles, and are seen during total eclipses of the sun. In October, 1868, Sir Norman Lockyer announced to the Royal Society that he had devised a means of observing these flames whenever the sun was shining, and that one of the luminous gases in them could not be identified. In his words, "we had to do with an element which we could not get in our laboratories, and therefore I took upon myself the responsibility of coining the word *helium.*"

Terrestrial Sources of Helium

In 1895, Sir William Ramsay, in connection with investigations of the element argon, discovered by Lord Rayleigh and himself in the earth's atmosphere, extracted a small quantity of gas from the mineral cleveite, and upon examining it found that it contained helium in addition to argon. Investigations have since shown that helium is widely diffused throughout the earth. It can be obtained from many types of rocks and minerals and is present in varying amounts in practically all natural gases and spring waters. It also occurs in the atmosphere in the proportion of about four parts to one million by volume. It has been proved to be formed by the disintegration of radium and other radioactive elements, and the α-particles shot out by these elements with velocities of about 12,000 miles per second are actually atoms of helium. Sir Ernest Rutherford has succeeded in converting a certain amount of nitrogen gas into hydrogen by bombarding the gas with the nuclei of helium atoms in the form of α-rays.

Some Properties of Helium

Next to hydrogen, helium is the lightest gas known. It is both non-inflammable and non-explosive and possesses 92 per cent. of the lifting power of hydrogen, so that it is a most suitable filling for airship envelopes. For aeronautical purposes, hydrogen can be mixed with helium to the extent of 15 per cent.; the mixture will no longer be inflammable or explosive in air. By the use of helium, the engines of airships can be placed within the gas envelope if desired. A further advantage of helium over hydrogen is that the buoyancy can be increased at will by heating or cooling the gas by electric or other means. Moreover, the loss of gas from diffusion through the envelope is less with helium than with hydrogen by about 30 per cent.

Helium can be used to fill thermionic amplifying valves for use in wireless telephony and also for filling incandescent filament lamps and arc lamps.

The lowest temperature yet attained on the earth was reached by Professor Kamerlingh Onnes, of Leiden, in 1908, by liquefying helium. The temperature was 490° F. below the freezing point of water, and was within 2 or 3° F. of absolute zero. It was found by Professor Onnes that a number of metals possessed a remarkable "super conductivity" at this temperature. Mercury, in particular, at the temperature of liquid helium, conducts an electric current ten millions times more easily than at ordinary room temperatures, and current started by induction in a coil of lead wire at the temperature of liquid helium maintained their intensity for more than an hour with but little diminution in strength. By the use of helium, therefore, not only has one element been changed into another, but the nearest approach to perpetual motion has been found.

Helium in Natural Gases

In 1915 Sir Richard Threlfall suggested that an inquiry into the helium content of supplies of natural gases within the Empire from the point of view of their development for aeronautical purposes should be carried out. The United States took up the subject when America entered the war two years later. A survey of all the natural gases within the Empire made by the writer and his associates showed that those from Ontario and Alberta, Canada, were richest in helium, though the proportion was relatively low, being about one third per cent. of the natural gases. The supply from sources in Great Britain is almost negligible, the natural gas at Heathfield, Sussex, having a helium content of only one fifth per cent., and that from the King Spring, Bath, of one sixth per cent.

No natural gas within the Empire has been found to contain as much as one half per cent. of helium, whereas in the western states of America, especially in Texas, natural gases exist which contain from one to two per cent. of helium, and some springs in France have as much as five per cent.

From 30,000 to 40,000 cubic feet of helium gas are now being extracted daily from natural gas in the United States. The gas is being compressed in steel cylinders and stored for use in airships and for other purposes, and its export is prohibited by law. Until the spring of 1918 not more than about 100 cubic feet of helium had ever been collected, and its market price was about £300 per cubic foot; since then, nearly three million cubic feet of the gas have been produced in the United States for use in the U. S. Army and Navy, and their new airships of the rigid type are being inflated with helium instead of hydrogen.

From ten to twelve million cubic feet of helium could, however, be obtained annually from natural gases in Canada, and the gas has such direct bearing upon problems of scientific and practical importance that the governments of Great Britain and Canada might, even from the point of view of national safety, legitimately be asked to follow the example of the United States and operate the plant which was constructed during the war and operated for a time at Calgary. With this plant it was shown that helium of high purity could be produced at less than five pence a cubic foot.

Low Temperature Research

Much of our knowledge of low-temperature effects we owe to the brilliant work of such distinguished men as Andrews, Davy, Faraday and Dewar. The discovery of the rare gases helium, neon, argon, krypton and xenon we owe to Lockyer, Rayleigh, Ramsay and Dewar. A fitting memorial to the work of these great men would be a laboratory for the purpose of making still further progress in the field of low-temperature research—a field in which British men of science have made such brilliant and notable advances. With suggestions received from Professor Kamerlingh Onnes, of Leiden, and with financial assistance received from the Honorary Advisory Council for Scientific and Industrial Research, of Canada, the Carnegie Foundation for Research and the University of Toronto, such a laboratory containing a magnificent cryogenic equipment has come into being in the Physical Laboratory of the University of Toronto. With it large supplies of liquid air, liquid hydrogen and liquid helium can be obtained.

This cryogenic laboratory was opened on January 10, 1923, and on that occasion demonstrations were given of the production of

liquid air, liquid hydrogen and liquid helium in quantity. It is hoped that the facilities of this laboratory will be used to the fullest extent by workers in low-temperature research.

THE PRINCIPLES OF FINE MEASUREMENT

By J. E. SEARS

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THE term "fine measurement" may be employed, even in relation to simple determinations of dimensions, in two or three different senses. It may refer to (1) the ascertainment—not necessarily with great proportional accuracy—of the sizes of extremely minute objects or of very small displacements; (2) the measurement of very small differences in dimension between objects of more considerable size; or (3) the determination, with the highest possible degree of precision, of the absolute sizes of various objects in terms of one of the recognized standard units of length. It is the object of the present article to deal with measurements of the second and third classes, of which the third presents, intrinsically, much the more difficult problem. However, by suitably arranging the work, measurements of the third kind can be obtained in many cases by calculation from observations of the second kind, and advantage should be taken of this simplification wherever possible.

STANDARDS

Whatever the nature of the measurement to be undertaken, the object, essentially, is the determination of some dimension in terms of the reference standard, and the nature of this standard calls first for consideration. The principal primary standards of length in use at the present day are the British Imperial Yard and the International Meter. Both these units of length are purely arbitrary, being each defined as the distance, at a certain specified temperature, between the centers of two fine lines scribed on small polished areas in the neutral plane of the cross-section of a material bar which is used as the ultimate representation of the unit. The British Imperial Yard is laid down on a bar of Baily's metal (copper 16, tin 2½, zinc 1) 38 inches long by one inch square, the graduation marks being on gold studs let in to the bottom surfaces of two circular pits, one half inch in diameter and one half inch deep, one inch from either end of the bar. The standard temperature is 62° F. The International Meter is laid down on a bar of

platinum-iridium (platinum 90 per cent., iridium 10 per cent.) of X-shaped cross-section, the neutral axis being exposed throughout its length. Its standard temperature is 0° C.

The graduation marks are arranged in the neutral plane of the bar in order that the distance between them may not be affected by the compression or extension which may occur in the upper or lower fibers of the bar owing to the mode of distribution of its weight upon its supports The supports are so arranged as best to minimize the effects of the flexure of the bar in respect of the difference between the free, unstressed form of the neutral plane, and the slightly curved shape which it assumes when the bar is resting on the supports under the action of its own weight. In the case of the British Imperial Yard, the supports consist of a series of eight equally spaced rollers, interconnected by a system of levers in such a manner that each roller takes an equal share of the weight. In the case of the International Meter two rollers only are used, spaced in such a manner that the distance between the graduation marks on the bar is at its maximum possible value, with the result that small errors in setting of the rollers have negligible effect on the measurements.

Each of these bars being of metal, their lengths vary with changes of temperature. The length of the bronze yard bar increases by about 10 parts in a million for each 1° F. rise in temperature, and that of the platinum-iridium meter bar by about 8 parts in a million for each 1° C. It is therefore of the greatest importance in the employment of these standards to ensure that their defining lengths are observed at exactly the right temperatures. Similar remarks, of course, apply to the objects to be compared with them, and where very precise measurements are concerned, the problem of accurate temperature control frequently represents one of the principal difficulties to be overcome.

Mechanical Comparison of Line Standards

In comparing the lengths of two standard bars it is usual to set them up side by side on rollers supported on two independent girders contained in a water bath mounted on a carriage, which is capable of being moved in a direction perpendicular to the length of the bars. The graduation lines are observed by means of a pair of microscopes rigidly supported in such a manner as to be unaffected by the movement of the carriage, focussing being done by adjusting the positions of the girders on which the bars are supported. The water in the bath is well stirred, and the temperature of the bars is ascertained by means of thermometers placed in the water with them. An electrical thermostatic device is used to

maintain the water at the desired temperature. By the movement of the carriage first one bar and then the other is brought into view, and the positions of the graduation marks are read off by means of cross-wires contained in the micrometer eyepieces of the microscopes. The differences between the observed readings, duly corrected for the known errors of calibration of the thermometers and microscopes, and for the coefficients of thermal expansion of the bars if the temperature has not been exactly adjusted, give finally the value of the difference in length between the latter. In some cases, where it is not possible to immerse the bars in water, the whole room containing the apparatus has to be thermostatically controlled and the apparatus itself very elaborately screened to protect the bars from the effects of the body heat of the observers.

Great precautions have also to be observed in order to eliminate various possible sources of error. The two bars are observed alternately several times in succession, and the observations must be so arranged in respect of time that the mean epoch of observation is the same for each bar, and also for the thermometers. Otherwise, any gradual change of temperature taking place during the course of the observations may affect the results. The bars must be reversed end for end in turn, and interchanged upon the girders, all the observations being repeated in each configuration, or slight differences of appearance of the lines under the microscope or changes in distribution of weight may have an effect. Each observer must take an equal number of observations of each end of each bar under each microscope, or the personal asymmetry of the observers' sight may have an influence, and, unless the cross-lines in the two microscopes are equally thick and equally spaced, the effects of personal error will not be fully eliminated unless each observer finally repeats all his observations viewing from the back of the apparatus instead of the front, so that the appearance in the microscope is changed from right to left.

In many cases, if the two standards or objects to be compared are known to have the same coefficient of expansion, the problem of temperature control can be greatly simplified, as it is then only necessary to ensure that both are brought to the *same* temperature, without the necessity of knowing exactly what that temperature is. A particular case where this is readily and automatically secured is in the operation of determining the values of the subdivisions of a graduated metal scale in terms of its whole length. For this purpose a comparator is employed in which the carriage can be traversed in the direction of the length of the bar. Two microscopes are used, as before, fixed at a distance apart corre-

sponding to one of the subdivisions it is desired to determine. Readings are taken on the graduation marks defining this subdivision, and the bar is then moved along until the next nominally equal subdivision comes into the field, and its graduation marks are similarly observed, the operation being repeated until all the nominally equal subdivisions have been compared with each other. In this way, for example, the values of all the decimeter intervals of a meter bar can be determined in terms of its total length. The bar being a single piece of metal, it may reasonably be assumed that each portion of it has the same composition and coefficient of expansion, and also, since it is a good thermal conductor, that the temperature throughout its length is uniform at any given moment. So long, therefore, as the rate of change of temperature is small and steady, if the observations are properly arranged so that the mean epoch of reading each subdivisional interval is the same, errors in measurement due to temperature are entirely eliminated. The operation also illustrates well the advantage of always comparing dimensions nominally equal, since only the small differences have actually to be measured, and errors of calibration of the microscopes are therefore of little effect.

Constancy of Standards

Another very important consideration is the actual constancy in length of the material standards themselves, in respect of time. Variations may occur due either to actual molecular changes in the substance of the bars or to minute damage done to the defining lines in the periodical cleaning which is inevitable, no matter how carefully the bars are kept. There is evidence that the present British Imperial Yard has probably shortened to the extent of about two ten thousandths of an inch from the former cause in the 80 years since it was constructed, while it has recently been ascertained that the two working copies of the International Meter, used at the Bureau International des Poids et Mesures at Sèvres to control other copies, have changed about 0.0004 mm in the last thirty years—probably from the latter cause. There is also the risk of damage due to shock in transport. A nickel copy of the meter used at the National Physical Laboratory, which had been quite stable for some fifteen years, was recently discovered to have changed about 0.0005 mm after being sent to Sèvres for reverification, though, so far as is known, every precaution was taken to avoid accident.

With all these difficulties in mind, it is natural to seek for some alternative type of standard, for preference a natural standard re-

producible at will in any national laboratory, and a possible standard of this kind is to be found in the wave-length of light. Professor A. A. Michelson by one method, and MM. Fabry and Perot by another method, some fourteen years later, determined the number of wave-lengths of certain lines in the cadmium spectrum in terms of the international meter, and obtained remarkably concordant results; and at the last meeting of the International Committee on Weights and Measures (Metric) a resolution was adopted accepting in principle the eventual adoption of the wave-length as the ultimate reference standard of length so soon as the best conditions for reproduction of uniform sources of light waves, and the best mode of applying them for the purpose, should have been fully investigated and determined This work is now being undertaken in the various national laboratories. It is not, of course, an easy problem, as many conditions—*e.g.*, those of the atmosphere through which the light-waves pass during measurement—have to be standardized, or the effects of their variations allowed for, before uniform results can be obtained.

End-Standards

Before practical use can be made of a light-wave standard for purposes of everyday measurement, it has, of course, to be compared with some material standard suitable for use in the ordinary mechanical processes of measurement. For such work two kinds of standard, line-standards such as we have already been considering, and end-standards, defined by the distance separating two parallel flat terminal faces, are required. For most purposes of engineering measurement the latter are the more important, and at present they have to be derived from the former—one of the most difficult operations in metrology. Wave-length measurements, however, are conducted by observing the distance between two plane parallel optical surfaces by means of the mutual interference of light rays reflected at them, so that, provided an end-standard of sufficient perfection can be produced, it is evidently more convenient to use such a standard, rather than a line-standard, as the primary material representation of the length unit derived from the wave-length.

Recently a great improvement in the perfection of finish of plane parallel end-standards has been achieved at the National Physical Laboratory by Mr. A. J. C. Brookes, who has succeeded in producing cylindrical standards of a yard or meter in length, the ends of which are polished flat, parallel and square with the axis of the cylinder to within a few millionths of an inch over the

whole area of faces, one inch in diameter. The introduction of these very refined gauges is likely to facilitate the adoption of the wave-length standard.

The mechanical comparison of such gauges, once the principal standard has been derived from the wave-length, can be carried out to a very high degree of accuracy by means of the tilting level comparator, devised by Messrs Brookes and Sears. The two gauges to be compared are set up side by side on a horizontal turntable, with their axes vertical, and a sensitive level, carried on two ball feet, is allowed to rest upon their upper faces The indication of the bubble is noted and the level removed. The turntable is rotated through 180°, so as to interchange the position of the two gauges beneath the level, which is then allowed to rest upon them once more, and a second reading of the bubble is taken. The difference between the two readings gives the measure of the difference of length between the two gauges.

The finish of the end faces of these gauges is so perfect that two or more of them will "wring" together, in the manner of the now well-known Johansson gauges, to form a composite gauge, and to obtain the lengths of shorter gauges of the same type in terms of the yard or meter, different combinations of nominally equal total length are wrung together and compared in the above way. Here again only small differences are ever measured, and the arrangement of the apparatus is such that the groups being compared can easily be brought to the same common temperature, and are never handled during the measurements, so that, provided all the pieces are made of steel of similar quality, and their coefficients of expansion hence equal, the temperature difficulty is overcome.

Optical Interference Method of Comparison

Shorter gauges, with flat parallel end surfaces and "wringing" quality of finish, were first introduced by the Swedish firm of Johansson, and are now being made in England by the Pitter Gauge & Precision Tool Company by a patented process developed at the National Physical Laboratory by Messrs. Sears and Brookes. Their calibration is effected on precisely the same principles as apply to the longer gauges, and may also be carried out on the tilting level comparator, the accuracy finally attainable in the standardization of a one inch gauge being of the order of 0.000001 inch. Alternatively it is possible to measure these gauges, and at the same time obtain a visual estimate of the degree of perfection of their surfaces, by the direct application of the principle of optical interference If a glass plate with an optically worked flat surface be

placed close and nearly parallel to one of the surfaces of a gauge, and viewed in parallel light, a series of interference bands is seen which constitute, in effect, a contour map of the surface of the gauge, the spacing of the bands corresponding to successive intervals of about 0.00001 inch. If the opposite face of the gauge be wrung on to another optical flat, the interference pattern formed between the first optical flat and the surface of the gauge can be compared with that formed between the two optical flats, and by repeating this with light of different known wave-lengths and comparing the results it is possible to ascertain the exact length of the gauge in wave-lengths without any further measurement. This method can only be applied to short gauges, as the interference fringes are not seen unless the distances are small. Measurements can be effected by this method, also, to an accuracy of a millionth part of an inch

PHOTO-ELASTIC COMPARATOR

A third method of measurement of the same high order of accuracy is by means of elastic strain, coupled with the use of an optical lever Two machines operating on this principle have been made and are in use at the National Physical Laboratory. Both give a movement to a spot of light of about 0.3 inch for a change in length of 0.00001 inch. In one the gauge is measured between flat parallel anvils, as in an ordinary measuring machine, and in the other by point contact between three balls on one face and one on the other, this giving a geometric location The essential feature of these machines is the complete elimination of all friction and backlash, such as is unavoidable with most types of mechanical indicators and with any screw-thread micrometer, where an oil film is interposed between the screw and the nut. The indication in these machines is an optically magnified image of the elastic displacement of a certain part which is deliberately made weak for the purpose, an initial mechanical magnification being afforded by means of a lever hinged elastically to the moving part. The rest of the machine is constructed with extreme rigidity, but its sensitiveness is such that a relatively small pressure by the hand is sufficient to cause an appreciable movement of the indicating spot.

It is of interest to record that, with gauges of sufficiently perfect finish, it has been found possible not only to obtain calibrations consistent among themselves to a millionth part of an inch by these various methods, but also to secure agreement to this order of accuracy between measurements of the same gauges made in different countries. There is one point, however, in which the optical interference method differs from the mechanical contact

methods. In the former the length of any individual gauge is determined by means of reflection in its metallic surfaces. In the latter the length is ascertained by computation from the results of comparisons between a number of built-up groups of the same nominal total length. It has been found that the gauges will not wring together if perfectly dry, and that if too freely greased they will slide easily on each other. To obtain good wringing it is necessary to have a trace, but only a trace, of lubricant between the surfaces, and this lubricant forms a film which has a certain thickness The nature of the operations is such that in the determinations made by mechanical contact, the resulting value of the length of any gauge is always associated with the thickness of one wringing film, which may be supposed to be distributed one half on either end. Since in the normal use of the gauges these films are actually present, the result so obtained is the actual effective length of the gauge But it differs from the length found by optical interference to the extent of the thickness of one wringing film It has been ascertained by comparing the results of mechanical and interference measurements of the same gauges that the thickness of a wringing film is reasonably constant, and varies from about one millionth of an inch when alcohol is used as a lubricant to three or four millionths when paraffin or vaseline is used.

STANDARDIZATION OF ENGINEERS' AND OTHER GAUGES

The flat parallel-ended gauges we have so far considered may be regarded as standard reference gauges for any desired dimensions In the practical application of measurement, the objects, the sizes of which it is desired to ascertain, are usually of much more complicated form, and in their measurement it is generally necessary to make use also of other types of standard gauge; for example, cylindrical or spherical gauges. The sizes of these have first to be determined by comparison with the flat-ended gauges, and in these comparisons a new difficulty arises. The material—usually hardened steel—of which the gauges are made, is elastic, and when the gauges are placed under pressure between the faces of a measuring machine, their surfaces become deformed. With the flat-ended gauges, between flat parallel measuring faces, the pressure is distributed over a finite area, and the deformation is negligible, but with cylinders or spheres it is concentrated along the line or point of contact, and in this case it becomes appreciable. As an example, the total compression in the case of a steel sphere, one inch diameter, measured between plane parallel measuring faces under a load of two pounds, amounts to about 0.00005 inch—

this amount including also the indentation of the measuring faces. In comparing a sphere under these conditions with a known flat-ended gauge, a correction of this amount would have to be applied to the observed result.

A recent development in the art of fine measurement, introduced by the National Physical Laboratory during the war, is the optical projector, devised by Mr. E M. Eden, and now made in two well-developed forms—the horizontal and vertical types. This consists essentially of a kind of magic lantern in which a beam of parallel light is directed on to the object to be examined, a magnified image of which is produced by means of a suitable lens upon a distant screen The whole success of the apparatus depends, of course, on finding a lens combination capable of giving an undistorted image over the whole of a field of view of considerable area. This was Mr. Eden's achievement, and once accomplished it became possible to compare the shapes of profile gauges, screw gauges and other similar objects with accurately-drawn magnified diagrams of their normal outline. The apparatus was of the greatest value during the war in the verification of engineers' gauges for munition supplies.

More recently yet another application has been found for it in the examination of pantograph records of the profiles of objects otherwise inaccessible to direct optical inspection. To get a one to one reproduction, exact within one ten thousandth part of an inch, involves special design and extreme care in workmanship, but has been found to be not impossible, and an apparatus of the kind, designed and made in the metrology department of the National Physical Laboratory, is now in regular use for the measurement of gears. A ball at the tracing end is carefully traversed around the profile of a tooth, and a record is traced on smoked glass by a fine needle at the recording point. This trace is then projected on the screen at a magnification of 50 times, and it is found quite practicable to read off errors to an accuracy of one ten thousandth of an inch.

The applications of fine measurement to engineering problems of all kinds are, of course, almost unlimited, and it would be quite impossible in a brief sketch such as this to attempt to describe them in detail. A collection of typical instruments and methods is exhibited by the National Physical Laboratory in the Engineering Hall.

THE CIRCULATION OF THE ATMOSPHERE

By Sir NAPIER SHAW, F.R.S.

The General Circulation

Recent progress in our comprehension of the circulation of the atmosphere derives largely from the law of relation between the velocity of air in steady motion and the distribution of pressure in any horizontal surface If one looks through the meteorological literature of forty years ago one can scarcely fail to be impressed with the notion that the writers always had in mind the conditions of starting and stopping and thought little about the long stretches of the travel of the air These stretches represent neither starting nor stopping, but steady or persistent motion under balanced forces, provided that we are permitted to include among the forces the effect of the rotation of the earth, which can be neither avoided nor ignored in any general atmospheric question. Yet it is no exaggeration to say that, with the motion of the atmosphere, starting and stopping are of no greater importance than they are in the passages of ocean-going steamers or non-stop trains.

We know that at the surface of the earth, from which most of our experience of weather is derived, there never is and never can be the steady motion which represents the balance between the gradient of pressure and the rotation of the earth, because the friction between the moving air and the earth or sea is always dissipating the energy of motion in eddies and ultimately in heat. To compensate for that loss and keep the motion steady, some force driving the air along its path would be required, but it is not forthcoming However, in the free air above the surface at the height of a kilometer or two, say, 5,000 feet, we need not think any longer about the disturbances due to the surface, and there, provided we are not directly involved in the convolutions of a cyclone, we may rely upon what is called "the geostrophic wind," that is to say, a wind along the lines of equal pressure (isobars), with velocity inversely proportional to the distance between consecutive isobaric lines, as a valid normal representation of the actual wind.

The consequence of this recognition of a simple dynamical relation between undisturbed wind and pressure-distribution is that a "geostrophic scale" always lies on the modern meteorologist's working chart, and when he wants to know the effective wind, disregarding the surface-friction, he lays his geostrophic scale across his isobars and reads off the result in meters per second or miles per hour as he pleases, or as it pleased the person who made the scale.

Use of Pilot Balloons

The general introduction of the use of pilot-balloons for determining the motion of the free air brings at one and the same time confirmation of the general principle and challenge of the individual facts. The assumption of the relation brings the winds of the upper air within the possibility of mathematical calculation in a manner which surprises all who take up the questions treated.

From this position, which is a very natural extension of Buys Ballot's law, it follows immediately that, if by any means we can determine the distribution of pressure at any level in the atmosphere, we can determine the horizontal velocity of the wind at that level by the simple process of laying a properly graduated scale across the isobars which represent the distribution of pressure; and the well-known barometric equation of Laplace gives us the means of calculating the pressure to be deducted from the value at the surface for any step of height when we know the temperature of the air at each level Such a determination of pressure in the upper levels, without observations carried out on the spot *ad hoc*, may be regarded as being beyond the discretion of a cautious meteorologist when he is dealing with the distribution of pressure of to-day or yesterday, as represented on a "synchronous" chart of actual pressure and temperature at a definite epoch, with all the peculiarities of the meteorological situation and its local incidents; but it is not at all out of the question when we come to deal with average conditions representing the mean result of observations for an individual month extending over so long a series of years that the transient local conditions are merged in the general picture.

The reason for supposing that we can calculate the distribution of pressure at an upper level from the observed pressures at the surface, with sufficient accuracy for general purposes, is derived from an entirely unexpected result obtained from records of registering instruments sent up on balloons, known as "sounding balloons." They carry instruments but no passengers. Things are so arranged that after an upward journey of from 6 to 10 miles or even more they burst and come down with the instrument. They reach the earth with the instrument and its precious record undamaged within about two hours of the start and within a hundred miles or so of the starting point.

Records obtained in this way, in Europe to begin with, and then in America, over the Atlantic Ocean, the Greenland seas, the Antarctic, the Victoria Nyanza, the Dutch East Indies and Australia, disclose the remarkable fact that, provided the temperature

at the surface is the highest of the record, the rate of fall of temperature with height is the same in any part of the world. There are a good many occasions, particularly in the winter of the locality where the sounding is made, when the surface is colder than the air in the layers immediately above it, and then there is no satisfactory starting point for calculating pressure in the upper air. Even on these occasions the régime of the fall of temperature with height according to the numerical rule asserts itself when a certain height has been attained; but that does not help us in the calculation of pressures in the upper levels because the starting point at the surface is off the line by an altogether unknown amount

Confining ourselves to summer temperatures, therefore, in which that difficulty does not arise, the pressures in the upper levels have been calculated with some assurance that we are at least within the range of probability, and on this basis the distribution of pressure over the northern hemisphere in July has been calculated for 2 km, 4 km, 6 km, 8 km and 10 km. The results are represented upon maps or models for the corresponding levels

Normal Atmospheric Circulation

Then we can use the distribution of pressure to calculate the normal atmospheric circulation at the surface and at the different levels It is very complicated at the surface, but becomes much simplified at 2 km. At higher levels the régime is clear; it is a circulation from west to east round the pole, not quite along circles of latitude because there is some distortion of shape consequent upon the transitions from land areas to sea areas and vice versa. The circumpolar circulation, west to east, extends to about latitude 30°; there it falls off very rapidly and along the equator and intertropical belt, there is a circulation in the opposite sense, from east to west

The two circulations at any level are not altogether independent: there are limited regions along the latitude 30° around which apparently air may pass from the equatorial circulation to the polar circulation and vice versa. These localities seem to supply moving belts which carry, or gear with, the east to west circulation on the southern side and the west to east circulation on the northern side.

The final conclusion has been reached by Mr. A. W. Lee that, so far as the polar circulation is concerned, and apart from the local disturbances due to coast-lines, the successive layers of our atmosphere are rotating "like a solid." The west to east velocity represents a travel a little faster than that of the solid earth, the values of the angular velocities of the successive shells being 1.03ω at 4 km and 6 km, and 1.05ω at 8 km in July, where ω is the angular

velocity of rotation of the earth. The corresponding velocity for January, as determined from a chart of isobars by Teisserenc de Bort, is 1 08ω. The intertropical circulation from east to west at high levels has an angular velocity of 0.92ω, but at lower levels it is much less. These figures mean that a shell, from 4 km to 6 km high, makes a complete rotation with regard to the earth from west to east, in 33 days in summer and 12 days in winter. Another higher shell at 8 km takes only 20 days to complete a spin even in the summer On the other hand, the higher air over the equator gets round the earth the opposite way in 12 days.

Local Disturbances of the Circulation

This simple régime, so easily imagined and remembered, does not, however, reach the surface. There we find a complication which only a carefully constructed map can represent. If we seek for an explanation of that complication we must remember that, whereas during the day, when the surface is solarized, the layer of earth and sea is receiving heat from the sun, the opposite is the case at night, and long before night in the regions of long shadows. There the surface is losing heat, and as an inevitable consequence air runs down the shaded hills more and more as the shadows lengthen and deepen. How much air runs down and how fast it runs we do not know, but we know that the flow must be there and huge pools of cold air must accumulate in the lower levels. Moreover, the process is irreversible; cooled air must stick to the ground, warmed air can not Hence we may regard the shadowed hills as pouring an immense volume of air on the lower regions, and thereby spoiling the simplicity of the distribution of pressure at the surface, and consequently that of the general circulation of the atmosphere in the lower layers.

There can scarcely be any question that the descent of cold air in this fashion expresses itself in the play of the general circulation as local modifications of the distribution of pressure at the surface and the formation of seasonal anticyclones The converse process, the ascent of warm air, is another story and a much more complicated one. The descending air, which of necessity clings to the hillside, can always take advantage of the cooling of the ground, and is thereby helped all the way; it goes down headlong like an avalanche; but to climb, air has to leave the ground and make its way through the layers above with only the trifling assistance which it can obtain from the absorption of radiation by the water vapor which it carries. While rising, it is subject to the automatic reduction of its temperature consequent upon the reduction of its pressure, if no heat is supplied to it. It loses heat at the rate of

1° C. for 100 meters, while the temperature of the environment falls off with height generally only 1° C. for 200 meters. The transparent air through which we see the sun and stars looks perfectly similar and homogeneous, and is all called simply air; but it is really stratified by its temperature into layers which are quite impervious to air rising from below, unless the rising air has the temperature necessary to furnish the key to get through.

> Facilis descensus Averni,
> Noctes atque dies patet atra janua Ditis,
> Sed revocare gradum superasque evadere ad auras,
> Hoc opus hic labor est.

Yet the air as we know it manages it quite easily by an ingenious trick It climbs to higher things on stepping-stones of its own dead water vapor It loads itself with moisture. As it rises it cools, and, if it is fortunate enough to pass the dew point, it condenses part of its moisture and takes over the heat of vaporization previously latent, but now set free. Fortified therewith, it passes on its victorious way upwards, sometimes with a rush great enough to carry up huge hailstones, until it meets its match in an environment that has less lapse of temperature with height than the rising air itself, in spite of its propensity to appropriate the latent heat of its accompanying water.

Up to a height varying with latitude from some 8 kilometers at a pole to 17 kilometers at the equator, there is a layer of air called the "stratosphere," where there is no fall of temperature at all with height. That layer even the wettest atmosphere can never penetrate, it can not be overcome either by *opus* or by *labor*—it is just impossible and impassable.

However, in the "troposphere," the region that lies between the ground and the stratosphere, all kinds of enterprises are possible to rising air fortified with a sufficient supply of water vapor: Clouds, rain, hail, snow, thunder, lightning and nearly all the other incidents of weather.

These striking phenomena are most notable characteristics of those local disturbances of the general circulation which are called cyclones or cyclonic depressions This has been recognized for a long time, and many meteorologists have thought that the cyclones really derived their energy from the convection of wet, warm air. Certain it is that if a rapid vertical ascent of air took place within the normal circulation, the circulation would be disturbed; the only question is by how much. It is also certain that if the layers of air in the middle atmosphere were traversed by air coming from below and passing out above, the rising air would carry with it from the middle layers more than its own mass, and the result of the eviction would necessarily be such a circulation as we may associate with

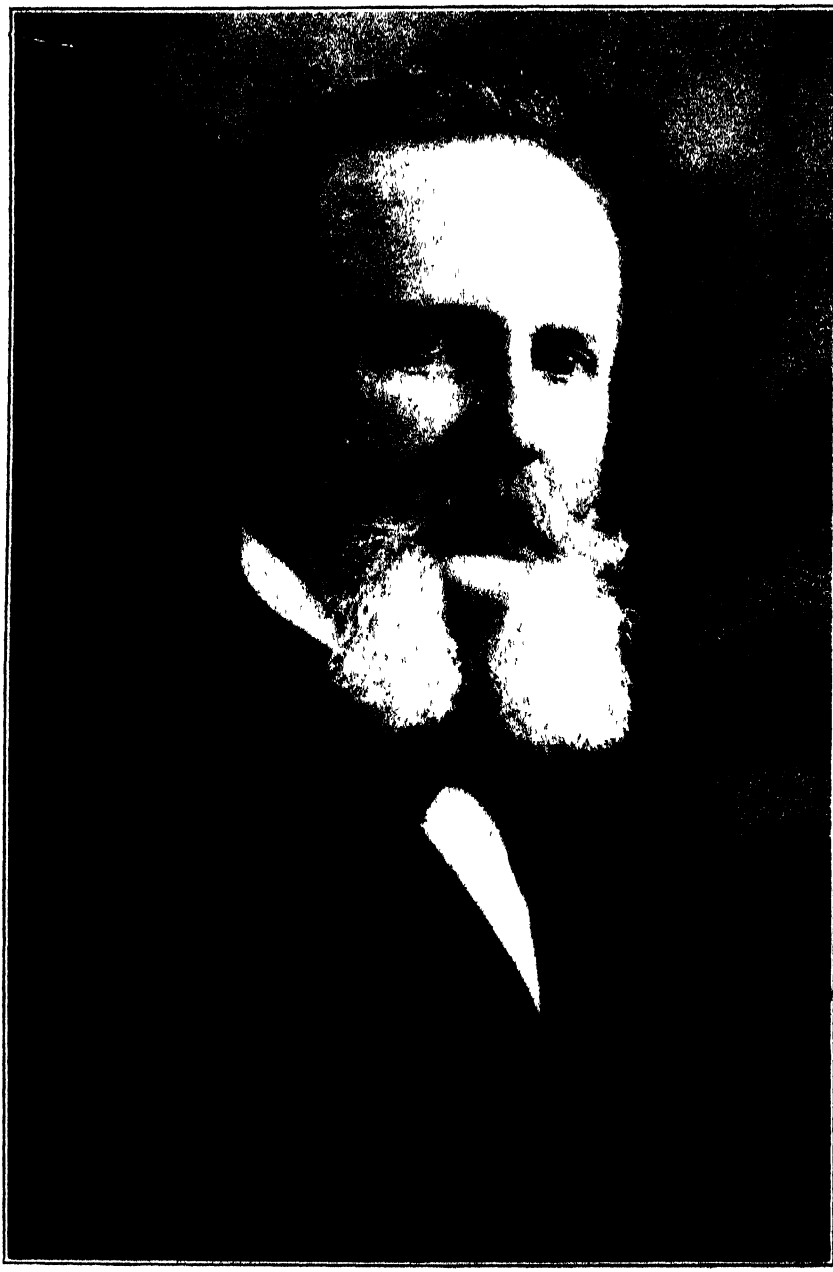
a cyclone freed from the friction of the surface. But, as yet, we can not speak with certainty as to the extent to which the origin or maintenance of the energy of a cyclone is due to the travel of air upward through the layers with the aid of the condensation of water vapor.

The new school of meteorologists in Norway traces the origin of cyclones to the mutual action of two currents of air across a surface of discontinuity and regards the accompanying weather as incidents of no dynamical importance, and a vortex as only the transient final form of wave-motion On the other hand, a Japanese student of the Imperial College has recently shown that a vortex with its recognized distribution of pressure, traveling along at the height of a kilometer, would produce automatically in the layers near the surface all the phenomena upon which the Norwegian school bases its conclusions.

Systematic Units of Measurement

It is acknowledged by all, however, that the phenomena of the atmosphere represent the working of an exceedingly complex air-engine or steam-engine and that the ultimate explanation of the local disturbances, as of the normal circulation, must be looked for in the quantitative relationships of all the physical quantities inherent in the atmosphere. Gravity, heat, work, temperature, wind-velocity, solar radiation, terrestrial radiation, vapor-pressure, all are associated and all will have to be combined when the explanation comes to be worked out If that be accepted, it is just as important for meteorologists to provide themselves with units of measurement on a systematic plan as it was fifty years ago for electrical workers. When we have to combine temperature with pressure in a formula, the measurement of temperature as a number of degrees from the freezing point of water has to be changed, whether the operator is aware of the fact or not. When we have to deal with the intricate relations of heat and work in the atmosphere to have to introduce a factor A or J, the very definition of which is uncertain, is adding to the inevitable *opus* and *labor*.

Hence one of the first steps in the explanation of the circulation of the atmosphere, when it comes to be written, will be the setting out of the measurements involved in systematic units; and therefore, as it will certainly be indispensable in the end when the work is done, so it will make things easier as the work proceeds. Thus we build our representation of the present state of knowledge of the circulation of the atmosphere and the means of extending it, upon the foundation of the representation of meteorological quantities in systematic units.



DR WILLIAM F. HILLEBRAND

The distinguished analytical chemist, chief chemist of the United States Bureau of Standards, Washington, who died on February 7.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON

SCIENCE SERVICE, WASHINGTON

AMERICAN BASEBALLS AND GERMAN BOATS

MARK TWAIN counts as one of the great events in human history the moment when the idea shot through the brain of Howe "that for a hundred and twenty generations the eye had been bored through the wrong end of the needle." Maybe some future author will count that moment equally momentous when the idea shot through the brain of Flettner that the smokestacks of an ocean vessel should not be used to carry off the smoke of the engine, for if they were revolved no engine would be needed. His experimental vessel, the *Buckau,* looks like an ordinary steamboat with two extraordinarily tall funnels. These are simply smooth cylinders, made of thin sheet steel, ten feet in diameter and sixty feet high. But no sooty steamy cloud comes out of the top and if you looked down into one of them you would not be choked with sulphurous fumes, and you would see no fiery flares at the bottom. All you would see would be a ten horse-power electric motor, which rotates the cylinder, yet the vessel is propelled with the force of a thousand horse-power engine. She has neither propellers nor paddle-wheels, neither furnace nor fuel, neither yards nor sails. Her only engine is the little Diesel for running the two electric motors inside the cylinders, and all that this needs is a little crude petroleum or tar-oil for its internal combustion.

The propulsive power of the ship is borrowed from the wind and she gets the best of it when the wind is not going her way, but blows abeam instead of astern. She can make headway against the wind only by tacking like a sailboat.

Since the *Buckau* has no boilers she needs no bunkers, since she carries no coal she needs no stokers, and since she hoists no sails she needs no sailors. Even the helmsman can be dispensed with, for no rudder is necessary. The ship can be steered by changing the rate and direction of the rotation of the cylinders, and this the captain might control by pressing buttons on the bridge. Reversing the rotors backs the boat. Running one rotor around one way and the other the opposite way turns the boat about as on a pivot. It would seem that such a ship would require no bigger crew than a bicycle. Anyhow the elimination of the boilers and the bunkers and the quarters of the crew should leave a lot of room for cargo and passengers.

The question of how the queer craft would behave in a heavy sea was settled on January 6, when the *Buckau* steamed out of harbor, no, I should say sailed out, no, I should say, rotored out, and made nine knots an hour in spite of, and with the aid of, a twenty-knot wind.

We should have expected the rotor ship to have been an American invention for two reasons: first, because the principle involved is the same as our pitchers employ in putting the curve on a baseball in the national game; and, second, because this force has been thoroughly studied in American laboratories of aerodynamics. A recent technical paper by

DR EDGAR T. WHERRY

Senior chemist of the United States Department of Agriculture, who has been able to treat soils so that sufficient acidity is produced for the growth of rhododendrons and trailing arbutus on ground which was previously too alkaline for this purpose.

Elliot G Reid, of the Langley Memorial Aeronautical Laboratory, is devoted to "tests on rotating cylinders" and gives the formulas by which the force can be calculated and photographs showing how air currents behave in passing around a cylinder. If the cylinder is stationary, the wind divides and goes by equally on both sides, producing no effect except a push on the windward side. But if the cylinder is revolving the wind receives different treatment on the two sides. On the side of the cylinder where the rotary motion is in the same direction as the wind, the air is helped along and speeded up by the friction of the surface of the cylinder. Consequently, the air pressure is reduced on this side and a sort of suction is formed On the side of the cylinder that is turning against the wind, the opposite effect is produced by the friction. That is, the flow of the air current is impeded, the air is compressed and its pressure on the cylinder is increased. The net result of diminishing the pressure on one

side and increasing it on the other is to produce a push acting on the cylinder at right angles to the wind, and it is this force that propels the Flettner boat.

The power of this cross-wind force depends upon the velocity of the wind, the height and diameter of the cylinder and its speed of rotation. The greater these are the stronger is the power developed. The Langley Laboratory finds that this force appears suddenly when the speed of the surface of the rotating cylinder rises to half that of the wind, and that thereafter the force increases steadily with the speed until the surface is moving twice as fast as the wind or faster. The experiments suggest that if the rotating shaft is made in the shape of a Greek cross instead of a smooth cylinder a greater cross-wind force may be produced, though it requires more power for rotation. The National Advisory Committee for Aeronautics has been engaged for a year in the investigation of the possibility of equipping airplanes with rotating cylinders, so as to utilize this cross force to impart a lift to the machine instead of depending wholly on the angle of the winds.

But neither our baseball fans nor our aviation experts have applied the principle to ship propulsion. So Anton Flettner has a free field and if his invention works as well as the German papers claim, he may appear before long in one of our ports with the ten thousand ton sailless ship that he plans to construct for transatlantic trade It will be as strange an apparition as the submarine that bobbed up at Baltimore loaded with German dyes and drugs during the war, and it will be much more welcome.

ATTEMPTS AT ARTIFICIAL GOLD

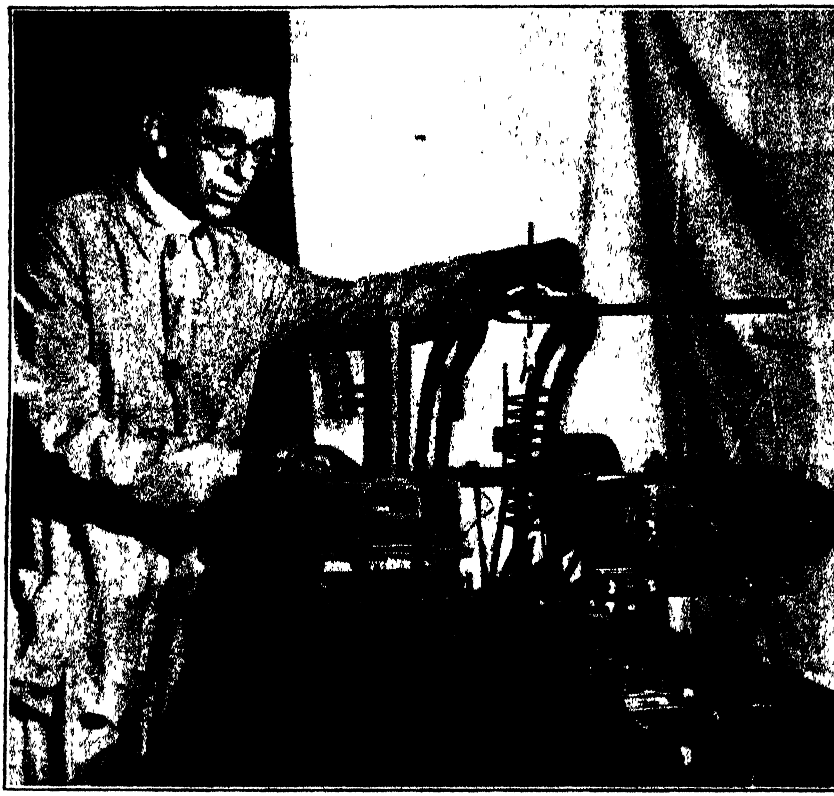
For some three thousand years, off and on, chemists have been trying to make gold out of the baser metals Just now they are on the quest again with as high hopes as the medieval alchemists and with better reason. We now know that some atoms can be broken to pieces and that some elements can be transmuted into others. The metal radium decomposes spontaneously into the gas helium and the metal lead. Professor Rutherford has split up the nitrogen atom into helium and hydrogen The helium atom weighs 4 and the hydrogen atom weighs 1. The helium is supposed to be made by the combination of 4 hydrogen atoms.

Now if you subtract the weight of the gold atom (197) from the weight of the mercury atom (201) you get 4. So it would seem that if you could knock out from the mercury atom a helium atom, or its equivalent, 4 hydrogen atoms, you would get gold.

But can you? That is the question. This may be, like many another chemical reaction, easy to write out on paper yet impossible to accomplish in the laboratory. But two chemists, a German and a Japanese, say that they have done it.

Professor A. Miethe, of the Photochemical Department of the Berlin Technical High School, who has been for years studying the discoloration of minerals and glass by ultraviolet light, found that the mercury vapor lamps used as a source for these rays ceased after a time to work owing to the deposit of a sort of soot on the quartz glass wall. He tested this deposit and got indications of gold.

Now it is not surprising to find a trace of gold in commercial samples of mercury, for mercury is one of the few liquids that will dissolve gold and is used to extract the precious metal from sand or ores. But the mer-



PROFESSOR FRANCIS A. TONDORF

Seen experimenting at Georgetown University with the new Galitzin vertical seismograph for the detection of earth tremors

cury in the lamps had been twice distilled to free it from all impurities and on analysis showed no trace of gold until after it had been subjected to the prolonged action of the electric current in the lamp. The quartz, the iron and the carbons of the lamp were also analyzed and pronounced gold-free. Miethe sent samples of these and of the mercury, before and after using in the lamp, to Professor Haber, the inventor of the Haber process for fixing nitrogen, who has been interested in the extraction of gold from sea water and had developed a very delicate method of estimating gold in minute amount. He reported finding gold and in some cases silver in the samples that came from the lamps. The amount varied from one to fifty-two parts in a billion parts of mercury.

From these experiments, which Miethe has carried on with his assistant, Dr. H. Stammreich, since last April, he concludes that some of the atoms of the mercury have been crumbled away by the electric current passing through the vapor, leaving gold as a residue. In his lamps he used 170 volts between the electrodes and ran currents from 400 to 2,000 watts for periods of 20 to 200 hours.

From the other side of the world comes the report of similar success in the manufacture of gold artificially. Professor Hantaro Nagaoka, of

the Tokyo Imperial University, has published a photograph of a deposit of gold which he obtained by running a mercury lamp for more than 200 hours under a voltage of 226. The gold obtained amounted to a milligram and a white metal that appears to be platinum was also produced.

In the United States, Professor H. H. Sheldon, of New York University, is engaged in repeating these experiments and doubtless many others are quietly carrying on the quest.

But there is as yet no apparent reason for the alarm that synthetic gold will upset the standard of the world's currency. The process, if possible, is too expensive to be profitable. Although gold is more than three hundred times as costly as mercury, yet the electric current would cost more than the value of the gold produced. This is likely to remain true, however much the efficiency of the apparatus is improved. Professor Miethe expressly warns the public that his discovery of the possibility of decomposing the mercury atom has no commercial importance and that speculation in this direction is rash and premature. There is no ground for the suspicion that the Germans are secretly manufacturing gold with intent to pay off all their war debts before the rest of the world learns how. If the aim is to produce wealth it would be much more profitable to find out how to get energy out of the atom than how to transform the elements by putting energy into the atom.

FLYING MOUNTAINS OF GRASSHOPPERS

Twenty-five trillion grasshoppers; forty-four million tons of them; covering an area of 2,280 square miles; all day long passing a given point These are the figures given for a swarm making its migration from Africa to Arabia across the Red Sea on November 25, 1889, and the British naturalist, Dr. G. Caruthers, who observed the flight, adds that it was not one of the largest swarms. He fails to furnish the figures on a real big one, perhaps because of inadequate facilities for taking a census of such a flighty population.

But the swarm that passed over Pretoria on May 25, 1891, is more generously and more accurately, or at least more definitely, estimated as composed of 130,842,144,000,000 individual insects. This swarm is said to have filled twelve cubic miles of space in the air.

The swarm that invaded Algeria in "the grasshopper year" of 1866 is estimated to have totaled 50,000 tons live weight on the wing. Apparently the insects were not counted in this case, but a count of the natives who died of starvation in consequence of their devastations is reported as 200,000.

On the island of Cyprus, in 1883, the lady locusts laid five billion cases of eggs. I don't know how many eggs constitute a case, in this case, but the total weight of the lay is estimated at 4,000 tons.

No statistics are given as to the number of those who constituted the eighth plague of Egypt, but the Bible tells us that:

> They covered the face of the whole earth, so that the land was darkened; and they did eat every herb of the land, and all the fruit of the trees which the hail had left; and there remained not any green thing in the trees, or in the herbs of the field, through all the land of Egypt.

I believe all these stories, and I would believe bigger ones if I could find them in any book at hand, for I can remember the grasshopper year of 1876 in Kansas. I can not give the number of these Colorado tourists,

because I was then too young to count over a billion, but I know that they darkened the land like a storm cloud and did eat every herb of the land and sent back to live with wife's folks thousands of hopeful young settlers in the western commonwealth We called them "grasshoppers," not "locusts," and I ought to know what they are since I have seen and swallowed them, and I am pleased to note that the Encyclopedia Britannica confirms our western term.

I can add a detail of the grasshopper plague not mentioned by the author of Exodus, that they were so numerous as to stop the trains by greasing the track Nowadays grasshopper grease is being used for lubricating airplane engines, a use we never thought of in 1876. It was recently reported that eighteen tons of dried locusts were shipped from South Africa to Holland for the extraction of the oil, which is said to retain its liquidity at very high altitudes.

It is nothing unusual to find great quantities of insects, especially grasshoppers, buried in snow fields and glaciers in the mountains. A very notable example of this is Grasshopper Glacier, in the Absaroka Mountains, a few miles north of Yellowstone National Park. The face of this glacier is marked with stratum after stratum of grasshoppers, and there are places on its surface where one can dig down a few inches with his fingers, and literally bring up solid handfuls of legs, heads and other parts of grasshopper shells. Presumably great swarms of insects attempting to cross the glacier have been chilled and trapped, and subsequent falls of snow have incorporated their bodies into the ice.

The most amazing thing to a chemist is the gigantic scale and swiftness of this production of grasshopper meat. The estimate given for the weight of the Red Sea swarm is some seventy times the weight of all the copper mined in America in a year. That is to say, it would take us seventy years to produce copper enough to balance the grasshoppers produced in seven weeks in this locality alone Biology is still far ahead of metallurgy as a large scale industry. A green crop converts the carbon, nitrogen, hydrogen and oxygen of the air and water into plant protoplasm, and then comes a flying cloud and in a few seconds all this is gone into grasshoppers and the ground is bare.

It is not a simple process for producing a single element, like the smelting of copper from its ore, but more like the operation of an automobile factory. A grasshopper is a more complicated machine than an automobile and even Ford can not catch up with the grasshopper in quantity production.

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MAY, 1925

ANCIENT CLIMATES[1]

SOME FACTORS OF CLIMATIC CONTROL

By Dr. W. J. HUMPHREYS

U. S WEATHER BUREAU

INTRODUCTION

A KNOWLEDGE of how climates are controlled and through what agencies they have been changed from one condition to another is an end within itself devoutly to be desired. Furthermore, it would be the means to other ends. It would enable us to infer from a known climatic condition the state of the factors that produced that condition; when we know the causes of effects, from effects we can infer causes. Let us see then how, in the main, climate is regulated to-day and to what extent its determinants are variable, for unquestionably its controls in the past were precisely the same as those of the present and only those now variable were then variable.

COSMICAL CONTROLS

Output of solar energy: As is well known, all the heat, or radiant energy converted into heat, that comes to the earth from the moon, the planets, the thousands of nebulae and the millions of stars is climatically entirely negligible in comparison to that which comes from the sun. If, then, the climatic changes of the past were largely caused by variations in the amount of radiation coming to the earth these variations in turn must have been owing to corresponding changes in our distance from the sun (considered below) or in its intrinsic radiational intensity; that is, its rate of emission per unit area.

Now, geological evidence shows that extensive mountain building always, so far as we can judge, was followed by a period of

[1] Papers presented at a symposium on "Ancient climates" held in connection with the meeting of Section E, American Association for the Advancement of Science, Washington, D. C., January 2, 1925.

cooler to colder climates. Hence to insist that the major climatic changes of the past were induced by corresponding solar changes is to urge either that the towering of the mountains was caused by the paling of the sun, or the paling of the sun by the towering of the mountains, or, finally, to assume for crustal folding and solar failure some mysterious common cause. If this logical deduction is untenable, as it seems to be, then however much or little the activity of the sun may have varied in the past that variation alone can not have been the sole cause, nor even the chief cause, of all the numerous climatic changes indelibly recorded in the book of ages

Solar distance: Since the intensity of heat received from a point source varies inversely as the square of the distance from that source, we have only to postulate suitable variations in our distance from the sun to account for any local climatic change whatever. No more enticingly simple explanation than this can possibly be found, but, however adequate it appears, the unyielding laws of celestial mechanics strictly forbid its adoption. True, the orbit of the earth about the sun does vary in shape owing to changes in the magnitude and direction of the resultant attraction between our planet and the rest of the solar system. Furthermore, these gravitational changes so rotate the orbit itself and axis of the earth that first one hemisphere and then the other, in a complete period of about 21,000 years, has its winters when we are farthest from our source of heat, and when therefore they are longest (the farther from the sun the slower we move) and coldest. Hence, it is argued, when the orbit of the earth is quite eccentric—departs widely from a circle—that hemisphere that is having its winters when most distant from the sun, aphelion winters, will rapidly accumulate ice and snow and thereby enter upon an age of glaciation.

It must be granted, of course, that the eccentricity of the earth's orbit does change and that this change does affect our climates. On the other hand, according to the rigid computations of the astronomer, this eccentricity has been nearly constant and quite small for fully 80,000 years—way back into the last ice age, and not just since its virtual close. Besides, there is no evidence, apparently, that glaciation occurred alternately in the northern and the southern hemispheres. Finally, no indication has been found that within the last 3,000,000 years, during most of which time the eccentricity of the earth's orbit has been comparatively large, there have been, as this theory would require, 100 or more extensive glacial advances and retreats in each of these regions. Variations, then, in the earth's orbit, though slightly altering our temperatures, presumably had but little part in bringing about the climatic

changes of the past. Indeed, so far as we know, they may as often have ameliorated as intensified these changes.

Obliquity of the ecliptic: Since the direction of the earth's axis in space changes but slowly, its conical motion having a period of about 26,000 years and its inclination to the plane of the ecliptic (plane of the earth's orbit) being practically constant through the ages, it follows that every year a series of seasons must succeed each other, as the sun passes from side to side of the equator, with temperature extremes, at least, roughly proportional to the inclination of this axis to the plane in question, that is, the ecliptic. If, then, we could play fast and loose with this inclination we easily might account thereby for any number of climatic changes of certain kinds. But here again that safest of all mentors, Mathesis, informs us that in accordance with the laws of celestial mechanics this inclination can never vary more than a degree or two on either side of the mean, and that with a period of a million years or more. Important climatic changes therefore can not be attributed to corresponding changes in the obliquity of the ecliptic—for these did not occur.

Perihelion phase: Since the earth passes the perihelion and aphelion of its orbit, or points closest to and farthest from the sun, respectively, about 2.5 minutes later from year to year, it follows that first the southern hemisphere, as is now the case, and then, in about 10,000 years, the northern, has relatively long cold winters and short hot summers. And as the longest winters exceed the shortest by about 4 per cent., while the total amount of heat received by the earth is the same for all half years (time of apparent passage of the sun from the one to the other of any two opposite points on the ecliptic) whatever their periods, it might seem, from the fourth power law of radiation, that the absolute temperatures of the two winter extremes should differ by approximately one per cent., or, say, 2.8° C. However, owing to the reservoir, or flywheel, action of the earth, the oceans especially, in storing up and giving out heat, no such temperature contrasts can occur. The longer winters begin a little milder than the short ones and end a little colder, but not enough warmer in autumn or colder in spring, and will not, so long as the eccentricity of the earth's orbit has its present small value, be of any appreciable climatic importance.

Sunspots: For some reason or reasons entirely unknown, spots of greatly decreased luminosity form on the sun in numbers that pass through an average cycle of a little over eleven years. These changes in the state of the source of our heat are accompanied, as we should suspect, by variations in the average temperature of the

earth. However, the range of these variations is small, roughly 1° C., hence, and also because the period of the cycle is short, of little interest in respect to climatic changes.

One might insist of course that the existence of small changes in the sun of short period indicates that the climatic variations of the past were caused by large solar changes of long period. This would be an easy solution of a difficult problem if we could find any adequate cause of the requisite changes of the sun. But as no such cause is even suspected we must continue at present to hunt for the sources of climatic changes in those factors of climatic control that are known themselves to have varied.

Passing through nebulae: It has been suggested that each glaciation of the past may have been owing to the enfeeblement of sunshine incident to the passage of the solar system through a nebula. Conceivably so, but if the luminous nebulae are as far away as the fixed stars, as they seem to be—many indeed vastly farther—then the Quaternary ice age, at least, could not have been thus caused, for we would not have become separated so far from the screening nebula in so short a time. But not all nebulae are luminous. Many are dark and of them we have practically no knowledge. If, however, they are islands of dead cosmic dust, in places of equilibrium under variously directed light pressures, then surely it never was one of them through which we passed—we never could have caught up with it in its flight on the approach of the sun.

Finally, the enfeebling of insolation in this manner would produce only a *lowering* of temperature, whereas we are confronted not only with the problem of accounting for much lower temperatures over various periods of the past than now prevail, but also with the equally difficult problem of accounting for much higher temperatures over vastly longer periods. Apparently, then, the nebulae offer but little help in the solution of our climatic problem. Warmer climates certainly were not produced by them, and it seems hardly possible that any of the colder were so caused.

Terrestrial Controls

Earth heat: The total flow of heat from within the earth amounts to only about 60 calories per year per square centimeter of surface, the equivalent, roughly, of one hour's sunshine. If this supply were cut off entirely, or, on the other hand, doubled, in either case the resulting climatic effect would be negligible. Furthermore, so far as we can judge from our knowledge of the sources of this heat (residual internal heat and radioactivity) its rate of delivery to the surface must have been very small for too long a time to permit the assumption that it was an important factor in the control of any recorded climate.

The idea that the warmer climates of the past were caused by the greater supply then of residual earth heat is, of course, hard to give up, but the laws of physics and the logic of numbers seem very positive that, however reluctantly, it must be abandoned.

Latitude: It has been urged that all the greater climatic changes, and many also of the minor ones, of any given place, have been caused by its change of latitude. Some have suggested that the earth as a whole retained the inclination of its axis to the ecliptic and despite that so turned from time to time as either spasmodically or gradually greatly to shift the positions of the poles. This simple way of explaining climatic changes however is strictly forbidden by celestial mechanics.

Others have argued that islands and even continents are but fragile cakes of frozen stone floating hither and yon on a sea of molten rock, thereby changing their latitudes and climates. This bold hypothesis has more than once commanded some attention, but seems now to be practically abandoned—wrecked alike by logic and observational evidence.

Another conceivable way of shifting latitudes would be to skew about the relatively thin outer shell of the earth over the plastic interior, leaving the axis of rotation but little changed. But we are not sure the interior is mobile to the degree this would require, nor, if it were, is there any known force capable of producing such a turning of the shell.

Clearly, then, the hypothesis that the known climatic changes have been caused by corresponding shifts of latitude is not tenable.

Land elevation: Although both logic and observation forbid the assumption that any portion of the surface of the earth may shift its position horizontally to a materially different climatic zone, exactly the reverse is true in respect to the vertical. We know that the height of the land, and especially the mountainous regions, above sea level has varied greatly through the ages. This has been owing in part to the transfer of water from the oceans and its accumulation in the form of ice on the islands and continents. Thus, if all the ice now so accumulated were melted every ocean would be raised by about 40 feet. The chief causes, however, of the rise and fall of plateaus and mountains are matters concerning which facts are still fewer than hypotheses. But they do rise and they do fall, and that is sufficient for our present purpose.

In the case of mountains the decrease of temperature with height is about 1° C. per 180 meters, hence in middle and higher latitudes many peaks even now rise well above the snow line. Obviously, too, when a high ridge lies for a great distance across the path of the prevailing winds (and many such ridges have existed as some now

exist) a relatively large amount of precipitation occurs on its windward slopes, while the lee side for hundreds of miles is more or less arid. Also, if the temperature is low enough, much snow falls to the lee of the crest and much more is blown over, so much indeed as, under favorable circumstances, to build a leeward progressing drift even higher than the ridge of rock that started it. Hence a mountain, if properly situated, and if the land beyond also is high, might lead to the filling of valleys with ice and the formation of a great glacier plateau.

Owing to their free and abundant radiation, all the more pronounced when snow covered, mountain crests and peaks also are colder than the free atmosphere at the same level. Consequently a vast amount of cooled air drains down their sides and adds its chill to the valleys and plains beyond. Clearly, then, high mountains and elevated plateaus make for bitter cold and abundant snow. On the other hand, the lowland climate is relatively mild for its latitude, and, in general, all the more so when unaffected by neighboring mountains. Land elevation, therefore, is a climatic control of very great importance, and one that has abundantly varied throughout geologic time; but it is not the only one.

Land and water distribution: As is well known, land intensifies and water moderates temperature extremes. Much of the heat absorbed by water merely produces evaporation. However, there also is considerable evaporation from the land, hence the summer contrast between the temperature of land and water is not as great as it would be if the land were absolutely dry. During winter, cooled surface water sinks and is replaced by warmer water from beneath as long as the supply lasts—all winter if the water is deep. No such convection, however, can occur on land. The surface of cooling land can not sink, as can water, beneath warmer layers below, but must stay at the top and merely get colder. The contrast, therefore, between land and water temperatures is greatest during winter. Hence also winter temperatures are more lowered than summer temperatures are raised, by land in the prevailingly windward direction. The eastern shore of Lake Michigan for instance has a far more equable climate, a climate well adapted to the growing of peaches even, than the western, and all because the prevailing winds cross the lake from west to east. Similarly, the winters of the Ohio Valley, dominated by northwest winds that have come long distances overland, are far colder now than they would be if the ocean covered, as of old it did, the whole continental valley from the Gulf of Mexico to the Arctic Sea. Numerous other similar examples could be cited in support of the thesis that the distribution of land and water is an important climatic control, but the fact is too well known to require further evidence.

Oceanic circulation: There are two great causes of oceanic circulation, namely, the drag of the winds and difference of density incident to variations in salinity and temperature. The first of these appears to be by far the more important of the two, at least in the movement of the surface water, the only portion that affects the state and condition of the atmosphere, or, in short, affects our climates. The great currents and drifts of oceanic water such as the Gulf Stream, the Japanese Current, the Labrador Current, the Humboldt Current and many others, moderate the heat of the tropics and wonderfully temper the cold of high latitudes. Oceanic circulation, therefore, is one of the most effective of all the controls of climate. Furthermore, it clearly has undergone many and profound changes incident to variations in the distribution of land and sea. If, for instance, the Gulf Stream could flow directly into the Pacific Ocean obviously the Scandinavian peninsula and at least the Highlands of Scotland would become glaciated. The great cyclonic center of action near Iceland would not exist. The belt of most rapid fall of temperature with increase of latitude, hence the belt of strongest winds and most frequent cyclones, would be much farther south over Europe. Storms would follow the Mediterranean far more frequently than they now do. Northern Africa would again become a wooded and watered region. Palestine and places beyond would rejoice in a greatly increased rainfall, but all at fearful cost to Europe.

On the other hand, if both the Gulf Stream and the Japanese Current had free and wide access to the Arctic Ocean the temperatures of that region certainly would be distinctly higher. There then would be fewer and milder outbreaks of cold air from the Arctic regions, fewer storms and gentler winds over the northern hemisphere and a host of other differences in the climate from that which now prevails. All that is necessary to work such profound climatic changes is the appropriate distribution of land and sea and the consequent regulation of the hot water heating system of the earth.

It has been argued that these apparently obvious conclusions are sadly in error, that even if the ocean covered the entire face of the earth the polar regions still would remain hopelessly frigid, and proof has been offered in the horrible climate of Kerguelen Island at 49° 40′ south latitude in the very midst of the Indian Ocean. The present climate of this island, however, is determined by conditions widely different from those assumed to give relatively mild polar temperatures. Antarctica, because of its considerable height and great extent, is shedding vast streams of frigid air onto the surrounding oceans, and continuously chilling them

with countless millions of tons of ice, both fixed and floating. Naturally, then, the surface of all the circum-Antarctic drift, the air above it, and the climate of every speck of land in its path, including of course Kerguelen, are cold and disagreeable. If, however, Antarctica did not exist there would be none of its drainage blizzards nor any of its vast fields of ice to chill the surface waters. Surely the temperature of the air would then be much higher, winds gentler and storms less frequent.

Salinity of the oceans: One of the most pleasing hypotheses ever offered in explanation of the mild temperatures of high latitudes is that based on the salinity of the ocean. If the increase of density owing to increase of salinity, incident to evaporation, in warmer latitudes should exceed the increase of density in high latitudes caused by low temperature, then this concentrated brine would flow as a warm and protected subsurface current to the colder regions, there rise to the surface, especially if the sea in those places were diluted by abundant precipitation or drainage, and give over much of its imported heat to the adjacent air. Such a circulation of the oceanic waters obviously would be of very great climatic importance.

That such a circulation might occur is partly indicated by the great sags in the isothermal surfaces as they cross the high pressure belts of the ocean, roughly centered along latitudes 30° north and south, respectively, where evaporation is much in excess of precipitation. The warmest deep water therefore is not along the equatorial belt, but along those belts, still in warm parts of the earth, where surface salinity is above normal.

However, not all the sinking of ocean water under the high pressure belts is attributable to increase of salinity. These belts, or sections, rather, of belts, are encircled by prevailing winds which, through the rotation of the earth, cause water to pile up within the encircled area, where of course it must sink.

Finally, the great bulk of ocean circulation, save the very deep and sluggish portions, is actuated by the wind, however much modified by the rotation of the earth, and deflected by continental and other barriers. These wind-driven currents also keep down to a minimum contrasts of salinity. Hence, while the so-called reverse ocean circulation may possibly have obtained at times, there is lacking both the conclusive evidence that it ever did, and rigorous proof that it actually could have.

Surface covering: The nature of the covering of land surfaces (the ocean surfaces are excluded because always essentially the same) whether, for instance, succulent vegetation, bare soil, including sand and rock, or snow, is of great climatological importance. Most soils and rocks are good absorbers of solar energy,

but poor emitters of earth (long wave length) radiation. On the other hand, snow absorbs solar energy, the greater portion of which lies in or close to the visible region, very imperfectly, as is obvious from its brilliant white glare in sunshine, and emits earth radiation twice as well, roughly, as bare soil or rock. Clearly, then, an extensive covering of snow, because it reflects so great a portion of sunlight, affects the region concerned much as would a very considerable reduction in the solar constant, for reflected radiation had as well never existed so far as heating the reflector is concerned. In addition to this the snow covering, because of its comparative excellence as a low temperature radiator and its exceedingly small thermal conductivity will cool to still more frigid temperatures. Hence, as already stated, surface covering, at least as between soil and snow, if of wide extent, is an important climatic control.

Atmospheric circulation: Since the cold winds of polar regions flow equatorward, however devious the paths followed, and the warm tropical winds poleward, it is evident that atmospheric circulation tends greatly to equalize the temperatures of the globe. Furthermore, owing to this circulation the greater portion of evaporation, a cooling process, occurs in the warmer regions, and a large portion of the condensation, a process that liberates much heat, in the cooler regions.

Also, as explained above, it is the winds, mainly, that drive the ocean currents. Hence, atmospheric circulation also is an exceedingly important climatic control, however much it in turn depends on other things, such as zonal contrast in temperature, positions and heights of mountains and distribution of land and water.

Extent and composition of the atmosphere: Since the atmosphere absorbs solar radiation to some extent and earth radiation in a much larger measure it obviously protects our land areas from becoming scorched by day and frozen at night. Clearly, too, this action would vary with the amount of the atmosphere, other things being equal, above the places concerned. But we do not know to what extent the total quantity of the atmosphere has varied, though of course we do know that the amount above given areas varied with their elevation above sea level. This virtual variation of our thermally protective cover is one of the indirect effects of changes in elevation.

Only a small portion of the atmosphere, really less than one per cent. of the whole, is at all effective as a thermal covering. Water vapor, chiefly, carbon dioxide slightly, and ozone, also slightly, are the only portions of the atmosphere that absorb appreciable amounts of either solar or terrestrial radiation. All three

of these constituents are variable, the water vapor most of all and rapidly so in response especially to temperature. A cool earth would have a thin vapor blanket, a warm earth a thick one. The amount of carbon dioxide has varied very slowly and over long periods in response to vulcanism, and the relative rates of hoarding and releasing carbon and carbonates.

It happens, however, that in its relation to radiation carbon dioxide is but little different from water vapor, so that as long as there is far more water vapor in the atmosphere than carbon dioxide, variations of the latter are of minor importance.

The changes in amount of ozone, a constituent of only the high atmosphere, are not known, but depend, apparently, more on the state of the sun than on the condition of the earth beneath.

Seemingly, then, the variations of water vapor in the atmosphere, incident to temperature changes, positions and heights of mountain ranges, and distribution of land and sea, have produced far greater climatic effects than have the changes in carbon dioxide or any other atmospheric constituent.

Volcanic dust: That portion of volcanic dust that floats for months or years, as sometimes happens, in the high atmosphere beyond the reach of clouds, is both coarse enough to shut out much of the incoming solar radiation and yet too fine to keep in much of the outgoing earth radiation. It, therefore, produces an inverse greenhouse effect, and necessarily leads always to lower terrestrial temperatures than otherwise would have prevailed. Hence the extent to which volcanic dust has been a climatic control has varied according to the amount of such material spread from time to time through the upper atmosphere, the frequency of such occasions, for this dust drops out in the course of one to three years, and the condition of the earth, especially with respect to land extent and elevation at the time of explosive activity. This last condition, though very important, seems usually to be overlooked.

Conclusion

Of the many factors of climatic control, all those of extra-terrestrial or cosmical origin either are demonstrably small or unproved, and, apparently, unnecessary to assume in accounting for the known climatic changes of the past.

These changes have been many and some have been profound, and all, we believe, were produced essentially by the earth itself. We hold this thesis because with ever so constant an output of solar energy and uniformity of other astronomical elements certain alterations of topography and other terrestrial conditions, no greater than those known to have occurred, surely would profoundly affect the present climates of the world.

The warmer periods (for middle and higher latitudes especially) were, it is believed, at those times when the land areas were relatively restricted and of small elevation and oceanic circulation free and open to high latitudes. The colder periods, including the ice ages, were, presumably, at the times when land was extensive, mountains abnormally high, and oceanic circulation restricted, especially in the more frigid zones. At such times the climates would be at least relatively cool while the loftiest peaks and ranges outside the tropics would carry many a glacier of greater or less magnitude. Under these conditions our climates would be in a critical state. A few violent volcanic explosions, for example of the Asama and Krakatoa type, say one a year for a dozen years, might well be disastrous. Every thick veil of volcanic dust, such as here contemplated, and as occasionally has been formed within historic times, necessarily and appreciably lowers the average temperatures. This in turn, if, as assumed, land is unusually extensive in middle and higher latitude regions, would lead to a greatly extended snow covering during every season of the year. Such a covering, in addition to itself cooling, by virtue of being a good radiator, to still lower temperatures would return to space untrapped and unused a large percentage of the incident solar radiation—a virtual decrease in the solar constant. Finally, this cooling would be further intensified by the incident thinning of our protecting blanket of water vapor. More upper air charges of volcanic dust, no matter where originated, would of course still further lower our temperatures, whatever they might happen to be, but they would not be essential to the disaster already begun—one does not have to keep on pulling the trigger after firing a gun.

In short, the earth has, we hold, produced its own climatic changes through such potent agencies as land and water distribution, land elevation, oceanic circulation, atmospheric circulation, volcanic dust and surface covering, and will, we believe, by these means yet produce many another such change.

EVIDENCE OF INVERTEBRATES ON THE QUESTION OF CLIMATIC ZONES DURING MESOZOIC TIME

By Dr. TIMOTHY W. STANTON

It should be stated at the outset that I am presenting a question rather than a thesis, the question being whether there were climatic zones during the Mesozoic era. The evidence to be considered relates chiefly to differences in Mesozoic marine invertebrate faunas

which may possibly be attributed to differences in temperature of the waters in which they lived.

No one will question that the present fauna of the cold Arctic seas differs greatly from the fauna of tropical waters, and that a fauna of intermediate character inhabits the temperate waters between the two extremes. This is of course particularly true of littoral and shallow-water faunas which are subjected to zonal differences in climate with temperature range in surface waters from a little below freezing (-1.7° C., 29° F.) to summer heat (27.4° C., 81° F.). In depths below 1,000 meters the temperature is relatively uniform at a few degrees above freezing (3° C., 37° or 38° F.) and the faunas also show much less differentiation. A similar zonal distribution of faunas is recognized in the southern hemisphere. The geographical limits of these zonal faunas are not sharp lines and they by no means coincide with parallels of latitude. They are shifted long distances one way or the other by the influence of ocean currents, and many other elements such as the nature of the bottom, the amount and character of sediments received, the presence or absence of barriers of various kinds, food supply and many other things enter in to determine the boundaries of more local faunal provinces.

Among all the varying factors just suggested it is not difficult to recognize the influence of temperature on living faunas. Reef-building corals, for example, do not live where the temperature of the water goes below 68° F., and some of the more important groups of these corals live in still warmer waters with a minimum temperature of 74° F. The molluscan fauna of tropical waters shows its exuberance by a much greater number of species and genera as well as of individuals than are found in the boreal seas. Each zonal fauna has many characteristic genera which are either restricted to it or best developed and most common in it.

It is universally accepted that there are faunal realms and provinces in the modern seas and that a part of this differentiation is directly due to climate. The invertebrate faunas of the other geologic periods are also distributed in faunal realms and more local provinces. According to Ulrich this is true from the beginning of the paleontologic record. Ulrich[1] says: "Except in a very broad generic way, I question if there ever was such a thing as a cosmopolitan littoral or shallow-water bottom fauna. Some of these faunas doubtless attained great distribution in certain geologic times, but aside from a few highly adaptable species and genera, they have always been limited by barriers of some kind to smaller or larger areas beyond which they could not spread." In another

[1] Ulrich, E. O., "Revision of the Paleozoic systems," Geol. Soc. Am. Bull., Vol. 22, p. 366, 1911.

passage in the same work,[2] Ulrich states that "comparative studies of Paleozoic faunas in the northern hemisphere suggest grouping them into three major faunal realms; namely, (1) an Atlantic, (2) an Arctic and (3) a Pacific," which he divides into a number of local provinces. This classification which may be interpreted as an Arctic or boreal realm set off from the rest of the world sounds like the beginning of a zonal arrangement due to climatal differences, but it is not so interpreted. Ulrich himself says in another place,[3] "taking the geological marine record, as preserved in the rocks from the Cambrian to the Tertiary, it suggests equable, mild, almost subtropical climate over the whole northern hemisphere in all the ages represented." He does, however, accept the evidence of local glaciation in certain epochs and suggests that the deposition of a certain type of black shale may be due to a cool climate.

Schuchert[4] interprets the record as indicating an alternation of mild with cool or even cold climates, stating that when "during the geologic ages the lands were reduced to but little above sea level . . . there were world-wide mild climates."

The marine invertebrate faunas of the Mesozoic were certainly more or less localized, though some of them extended over wide areas. This was true to some extent even of the Triassic, which is generally believed to have had a world-wide mild climate, as indicated, for example, in the Lower Triassic when the same kind of a cephalopod fauna lived in India, in northern Siberia and in the western part of the United States. The differentiation into local faunas was still more marked in later Jurassic and in Cretaceous time. It was in the study of the distribution of these faunas, especially of the ammonites in them, that Neumayr[5] recognized a zonal distribution which he attributed to climatal differences. His zones were boreal, middle European and Mediterranean, each characterized by particular genera of ammonites, or the absence of them, and corresponding in a general way with the frigid, north temperate and tropical zones of the present day.

Since Neumayr's time much has been learned about the distribution of Jurassic and Cretaceous faunas in all parts of the world, and in consequence Neumayr's conclusions and some of the data on which they were based have been questioned by several geologists, notably Burckhardt,[6] who has stated that he has seen genera of ammonites supposed to be characteristic of each of Neumayr's

[2] *Op cit.*, p. 483.

[3] *Op. cit.*, p. 352.

[4] Schuchert, Charles, "Text-book of Geology," 2d ed., p. 447.

[5] Neumayr, M., "Klimatische Zonen während Jura und Kreidezeit," 1883.

[6] Burckhardt, Carlos, Soc. Cient. Antonio Alzate, Mem. 31, pp. 107–115, 32, pp. 79–84, 1911, 1912.

zones all associated in one bed in Mexico and even as far south as the Argentine cordillera. He also calls attention to the abundant occurrence in Mexico of the boreal pelecypod Aucella, which is so widely distributed in all the northern circumpolar region and along the Pacific coast from Alaska to Southern California. Perhaps if Aucella had been first discovered and described in Mexico instead of in Russia we would now be speaking of the great northern extension of a tropical genus. There is always the tendency to regard the place where a species or a genus is first found as its original home, but in this case there can be little doubt that Aucella is really a boreal form and boreal faunas were realities throughout Mesozoic time in spite of the fact that they sometimes extended far south of their usual range and at other times were displaced in at least a part of their area by faunas from the south. The alternation of boreal with Indian or Mediterranean faunas in the Jurassic and Cretaceous of the Pacific coast have been well described by J. P. Smith,[7] who made the very plausible suggestion that these faunal changes may have been in large part due to the alternate opening and closing of the Bering Sea passage between the Arctic and the Pacific. Whether these changes in the faunas meant great changes in the climate is not known. The association of ideas is such that boreal instantly suggests *cold,* and Indian or Mediterranean suggests *hot,* but in those distant periods of the past the differences in temperature may not have been and probably were not so great. Whatever may have been the cause and no matter whether it was associated with actual differences in temperature or not, the fact remains that there were boreal faunas in later Jurassic and in Cretaceous time and that there are suggestions of boreal faunas in the Triassic and even throughout the Paleozoic. It is equally true that there were distinctive Mediterranean or equatorial faunas, especially in the Cretaceous. Victor Uhlig,[8] who has studied especially the distribution of Jurassic and Lower Cretaceous faunas, recognizes four faunal realms, boreal, Mediterraneane-Caucasian, Himalayan and South Andean, to which possibly should be added a fifth, Japanese, but he states all these except the first can be combined into a broad equatorial girdle which is contrasted with the holarctic boreal faunal realm.

In this connection consideration should be given to that peculiar faunal facies well developed in several epochs of the Cretaceous, usually called the Mediterranean fauna, which is characterized by the aberrant rudistids and other reef-building pelecypods with corals and distinctive ammonoids and gastropods and in many

[7] Smith, Jas. Pervin, *Pop. Sci. Monthly,* 1910, pp. 482–484.

[8] Uhlig, Victor, Die Marinen Reich der Jura und der Unterkreide, Mittheilungen der Geol. Gesellsch. Wien. Bd. 3, pp. 329–448, 1911.

areas associated with great accumulations of limestone. It is distributed on both sides of the Mediterranean in southern Europe and northern Africa, and is recognized in Syria, India, California, Texas, Mexico, the West Indies and the northern part of South America. The character and distribution of this fauna, or more strictly speaking these faunas, strongly suggests tropical conditions. In Turonian time a special phase of the Mediterranean fauna characterized by Vascoceras and other peculiar ammonite genera has recently been recorded by Reeside in the western interior region as far north as southern Montana. This is in harmony with the known distribution of Metoicoceras, another southern genus of ammonites, as indicating the northward extension of southern faunas in Turonian (early Colorado) time. A little later, at the time when the Niobrara and Austin chalks were being deposited, there are greater differences between the northern and the southern faunas, but whether they were due to climate or to a connection with a northern sea or to differences in the character of sea bottom or to other conditions has not been determined. The Pierre and Fox Hills faunas of the Great Plains and Rocky Mountains region differ still more widely from the contemporaneous faunas of the Gulf and Atlantic coastal plain. The character of the sediments also differs widely in the two regions, and it may be that this fact, together with the probable absence of direct open marine connection, will account for the differences in the faunas.

Just here let me call attention to the chief difficulty in solving our question of climatic zones in past epochs. If the faunas of two regions are identical or closely similar we are justified in assuming that all the conditions under which they lived, including climate, were identical, but if the faunas are different it is very difficult to evaluate all the complex conditions of life that may have caused the difference and to determine whether climate really had anything to do with it. In the first place, it is necessary to be certain that the two contrasting faunas are exactly of the same age. If they are not the conclusions drawn from them as to climatic variations at a particular time will have no value. Then there are questions about the character of bottom, the composition, purity and depth of water, tides, currents and many other things, some of which can be determined with more or less accuracy and some can only be guessed at.

With all these uncertainties in mind and admitting the established fact that during most of Mesozoic time mild climate extended much nearer the poles than at present, it seems to me probable that there was some development of climatic zones with less contrasts than at present, so that the polar regions were somewhat cooler than the rest of the world, and that the warmest seas were in the equatorial region, as they are now.

GLACIAL CLIMATIC CONDITIONS

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OUR knowledge of the climatic conditions during glaciations is largely gained from studies of existing glaciers and the waning of the last Pleistocene ice sheets. During the growth of ice sheets, when accumulation exceeded depletion, the snowfall over the ice was great and the summer temperature low. Because of cooling of the air over the ice, strong permanent anticyclones were developed here. The precipitation, in accordance with G. C. Simpson's explanation of the snowfall in the Antarctic anticyclone, probably took place owing to the fact that the outblowing air, extremely cooled by radiation, was forced by fast traveling pressure waves to rise over the air in front. It was further cooled in the ascent, so that the water contained was precipitated at insignificant elevation as snow. Since the ice centers, especially those west of Hudson Bay and in Labrador, are now semi-arid or have slight precipitation, there must have been considerable transport of moisture from the seas in low and middle latitudes. Since evaporation probably was not greater than at present, in spite of the fact that the windiness was greater, the unglaciated regions likely received less precipitation than they do to-day.

During the disappearance of the ice sheets the climatic conditions in the glaciated areas must have been characterized by high, and on the whole progressively increasing, summer temperature, strong insolation, clear sky and insignificant precipitation in the form of both rain and snow. High temperature and strong insolation are the most favorable conditions for ice melting; and the depletion of the ice sheets was essentially brought about by rise in summer temperature and insufficient nourishment. Although the retreating ice border was followed by an Arctic tundra belt, the climate was not Arctic, as is distinctly shown by the rapid retreat of the ice borders. This belt was due to the cold ground, the cold winds continuously sweeping down from the ice and the utilization of heat in fusing the ice and heating the melt-water. The precipitation over the tundra belt and the occasional bordering steppe belt was as insignificant as over the continental glaciers. The aridity perhaps was a consequence of the temperature rise, since low temperature near the ground appears to be essential for precipitation in an anticyclone. The deficiency in precipitation on and just outside the ice sheets probably was made up in permanent low pressure areas and along storm-tracks farther away, thus caus-

ing, during the maximum extension of the ice sheets and the first time of ice recession, pluvial periods in the Great Basin, the Mediterranean region, etc.

Of the two decisive factors for glaciation and deglaciation, summer temperature and precipitation in solid form, the first of these is of greater importance.

UPPER PALEOZOIC CLIMATE AS INDICATED BY FOSSIL PLANTS

By Dr. DAVID WHITE
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Cambrian and Ordovician

Prior to the oldest records of land floras of which we have knowledge, paleobotany furnishes little evidence as to terrestrial climates. The blue-green algae were apparently abundant and widespread in the Ordovician and Cambrian formations. According to the views of many paleontologists, they were also represented in earlier periods, many and highly diverse fossils referred with more or less confidence to this order having been found in deposits of pre-Cambrian age. The presence of blue-green algae growing in shallow depths of the sea premises the penetration of sunlight and conforms the testimony both of the marine invertebrates and of the depositional features, which also indicate sunlight and wind in the very early Paleozoic. In this connection mention may be made of the occurrence of corals in the Ordovician and Silurian faunas of the far north, attention being called to the discovery of early Paleozoic formations richly fossiliferous above latitude 80 in the extreme north of Greenland.

Silurian

Slender branching sea weeds, growing erect and provided with structural features enabling them to stand alone in air, appear to have become adapted to amphibious or aerial vegetation for the first time in the Silurian. At least it is probable that the amphibious stage was past before the end of this period, although no fossil remains of algal types or, more properly speaking, of algal derivatives, evidently adapted to sub-aerial growth, are found in formations earlier than the Devonian.

Devonian

Much discussion has been given by many paleontologists and botanists to the emergence of sea plants which presumably found

most favorable environmental conditions in broad shallow tidal estuaries verging into low land marshes in a region of very moist and probably distinctly mild climate. A silicified peat from the older Devonian of Wales presents a biological and geological cross-section of such a very early swamp flora. Both scalariform tissue and punctate tracheids were developed in these early types, and one of them, Nematophycus, the trunk of which must sometimes have reached a diameter of 3 feet, presents a structure embracing rather loosely interwoven tracheids of very large size parted by irregular parenchymatous wedges so as to suggest a gymnospermous relationship. In fact, on the basis of this resemblance, the American material was first described under the name Prototaxities.

The floras of the upper and middle Devonian were of remarkably wide distribution in the northern hemisphere. Genera and even species ranged from the southern Appalachian region and southern Europe to Elsmere Land and Spitzbergen. Little is known of the foliage of the early Devonian land plants. A notable feature of most of the types in this flora is, however, the small size of the leaf, which in some cases seems to have been little differentiated from twig and branch, the latter being apparently flattened or angular so that the whole may perhaps be compared with the phyllodal development. One wonders whether some of the early land plants like Psilophyton (Hostimella) and Nematophycus were not, after all, amphibious. The great thickness of secondary wood in the latter suggests resistance to the pressure of wind and possibly of water rather than an engineering device for the support of a seemingly deficient top.

At later stages, in the Middle and early Upper Devonian, we find in some localities abundant remains of the early arborescent lycopods. These, known under the general term Lepidodendron, were really antecedent to both the Lepidodendrae and Sigillariae, and combine many characteristics of both. They were not large trees and were in general characterized by somewhat ropy-looking, sparsely forking branches, generally drooping; and by thin leaves which persisted for a long time on the larger branches. These leaves are chaffy and sometimes rigid in aspect, but in general they clothe the branches rather thinly, so that the leaf surface of these trees is comparatively small in proportion to the size of the trees. From the meager as well as rather peculiar leaf expansion of the earlier and middle Devonian land plants, notably the Psilophyton group, the inference may tentatively be drawn that less foliar expansion was needed in the vegetation of that day, due possibly to lesser air requirements or, perhaps, to so ample a supply of carbon dioxide that less leaf surface and digestive tissue were needed.

The definite climatic criteria offered by the middle Devonian land floras are scanty. It is, however, to be noted that the cells of certain types of wood of very widespread distribution and of structure referred to by most paleobotanists as gymnospermous, were very large and comparatively thin-walled; and, what is more significant, the wood, which is sometimes found in fragments as much as 2 feet in diameter, shows almost no trace of annual rings of growth.

The known floras of the Upper Devonian were not highly diversified, but they were already relatively highly organized, as proved by the presence of early forms of the cycadofilices. These are fern-like plants, some of which were arborescent, others vine-like, in which varying types of secondary growth were combined with fern-like types of structure, especially in the petioles and foliage. They were essentially flowering plants, since they produced pollen and primitive ovules, foreshadowing, in generally simple forms, the gymnospermous type. The production of pollen on branches separate from those bearing the ovules implies the good offices of winds. The protective covering of the ovules was evidently to safeguard the vitality of the seeds during seasons or on ground unfavorable for germination and growth. Rainfall during the greater part at least of the year is suggested; dispersion by flotation was probably prevalent. The typical Upper Devonian flora was remarkable for its distribution. Its characters are compatible with winds, abundant sunlight and annual or irregular dry seasons, especially in the later stages.

Mississippian

Following the post-Devonian uplift, the Mississippian flora begins with new species of a very limited number of genera, mainly of the lycopod and cycadofilic types, particularly of the genera *Triphyllopteris* and *Aneimites*. In the lowland country this flora was luxuriant, and, where the physiographic conditions were favorable, coals were laid down in swamps, a circumstance which means reasonably ample rainfall.

The early Mississippian flora ranged within the Arctic circle from northwest Alaska to Bear Island and Spitzbergen, as well as into the distinctly temperate zones. In the later Mississippian conditions were in general less favorable for land plants—at least in North America. The floras of this later stage are characterized by reduced foliage, and thick and sometimes recurved pinnules. Carbonaceous deposits are relatively rare. The xerophytic aspect of many of the plants found in eastern North America accords with the evidences of aridity or semiaridity prevailing at times, as is proved

by the deposition of thick masses of anhydrite, gypsum and salt. No luxuriant flora of late Mississippian age has, I believe, been found in any region of the earth. On the other hand, the intervals of greatest aridity in any region were less favorable for the deposition of lacustrine, fluviatile and estuarian plant-bearing deposits. Reduction of the plants was probably consequent to changing environment attending incipient mountain building and changes in the epicontinental seas.

It is probable that the beds of the Caney shale, which in eastern Oklahoma carry ice-transported boulders, belong to a generally inhospitable stage attending the post-Mississippian uplift in this region. Most of the Mississippian species and some of the genera were exterminated during the post-Mississippian revolution. In this last phase of the Mississippian the climate of the world undoubtedly varied considerably, but it can hardly have differed so drastically, with alternating changes, as during the relatively short interval of post-Tertiary time.

PENNSYLVANIAN

From the paleobotanical standpoint the post-Mississippian revolution is in most parts of the world more strongly marked than that following the Devonian. From a meager, stunted and comparatively insignificant late Mississippian flora, there arose in the early Pennsylvanian a very rapid differentiation of land plants, most of which were at the beginning derived from two or three Neuropteroid and Triphyllopteroid genera. In the middle and upper Pottsville (Westphalian age) we have, on the other hand, the most luxuriant and highly elaborated land vegetation of the Paleozoic era It was the period of very great—possibly maximum—equability of climate throughout great portions of the earth, even in high latitudes, as is shown by the extraordinary geographical range of identical genera and species. Warmth and moisture in amounts most favorable for plant growth are proved by rankness of terrestrial vegetation; great size of trees, plants and leaves; expansion of smooth bark to accompany the enlargement of trunk; large wood cells with thin walls and large intercellular spaces; great size of fronds and the development of aphlebiae—all indicating subtropical or possibly nearly tropical temperatures, in many regions. The absence of rings of annual growth, especially in the upper Pottsville and early Allegheny, points to well-distributed rainfall throughout the year, as well as the absence of winter frost. Abundance of coal predicates relatively copious rain. Fairly well-developed palisade tissue points toward sunlight.

The upper Pottsville, and the Kanawha in particular, are noted for the number of very delicate, laciniately dissected ferns and the presence of many long slender clambering or climbing ferns and fern-like types belonging to the genera Palmatopteris, Sphenopteris and Diplothmema Many of the ferns were membranaceous, and hydathodes for the elimination of excess water were present in many species and genera. The nearest relatives of some of the ferns are the Marratiaceae and Gleicheniaceae which now inhabit tropical and subtropical countries. Other plants are related to the cycads. The Calamariae, the forerunners of the living horsetails, were of colossal proportions and many of them were provided by a thick growth of secondary wood. The evidence for a very humid and subtropical or even milder climate, extending from low to high latitudes, with relatively little annual change in temperature, is cumulative and essentially conclusive The probable prevalence of winds is shown by large numbers of winged seeds; and the even distribution of rainfall throughout the year is indicated not only by the dilation of the basal portions of the trunks and by the development of knees in some of the trees in accommodation to a permanent water cover over the surface of the swamp, but also by the abundance of the heterosporous lycopods, the successful perpetuation of whose species was dependent upon the conjunction of megaspore and microspore by drift in the water. Further, many of the fruits of the cycadofilic and gymnospermous genera were provided by pollen chambers with closure to assure the success of delayed fertilization.

In upper Allegheny time, which is middle Pennsylvanian, the evidence for seasonal changes is more distinct. Faint annual rings are seen in some of the woods. A little later, however, in the Conemaugh and Monongahela formations, which comprise the upper part of the Pennsylvanian (Stephanian age), we find fairly clear evidence of lack of uniformity of distribution in rainfall throughout the year. Annual rings of growth of the woods are much more distinct. Probable annual dry seasons are indicated by the rapid disappearance of the heterosporous lycopods on account of irregularity or even failure for too long periods of the water to cover the ground of the swamp. Simultaneously we see in what are now the temperate zones the rapid increase of gigantic tree ferns provided with great thicknesses of internal ramenta with notable capacity for water storage. Meanwhile, the delicate membranaceous and clambering or liana-like ferns nearly disappeared and many of the plants, especially in the great genus Pecopteris and its allies, bore rather thick pinnules with coriaceous or villous coverings.

The fact that exactly similar physiological features are shown in the fresh-water basin as in the coastal coal fields, leaves no room for

possible explanation of them as halophytic, though in some cases they may be pseudo-xerophytic. Most of the known floras of the Pennsylvanian were growing in swamps or lowlands of coastal plains or broad inland basins. The period was one of generally well-developed base leveling.

Permian

The most interesting by far, as well as the best known, of all the glacial episodes of geologic history before the great Pleistocene ice age was that which took place near the close of the Pennsylvanian or in the early Permian. This "Permo-Carboniferous" glaciation was widespread in southern India, Australia, South Africa and that part of South America embracing, at least, a considerable portion of southern Brazil. In magnitude it far surpassed the extent of the Pleistocene ice sheets. Glaciation itself is proved by great deposits of till containing unquestionably glaciated boulders. The ice sheets of Africa and South America may not have reached tide level, and in India the glaciers may have moved in a great upland basin. In the Australian region icebergs seem to have broken away along sea fronts.

Within the regions of the influence of this greater cold there was developed a unique flora of curious types known as the Gangamopteris flora, though sometimes inadvisedly referred to as the "Glossopteris" flora. This flora, apparently meager as to variety of types, and seemingly composed largely of forms of low growth and very broad leaves, is found in all the regions where the physical evidence of "Permo-Carboniferous" ice action has been observed. It is distinctly a land flora and, therefore, its distribution, almost in its entirety, from southern India through Australia and South America, premises land connections between these continents as necessary for the free migration of the flora in early Permian time. Similarly, the distribution of some of the very curious types of early Permian reptiles lends support to the presence of such land bridges, the existence of which can, in fact, hardly be doubted. The circumstance that the Gangamopteris flora was at home in regions inhospitable to the cosmopolitan Permian flora of western Europe and America lends support to the hypothesis that migration between some of its habitats, notably between Africa and South America, may have been by way of Antarctica. There is in fact little doubt that this flora, or some of its lineal descendants, inhabited Antarctica at a later period when climatic conditions there were favorable for the growth of arborescent vegetation.

Strong, if not violently contrasting, climatic geography attended the "Permo-Carboniferous" period of cold; for, quite opposite to conditions prevailing in southern Asia and possibly to some extent in north central Asia, the earlier Permian floras in the Appalachian region of the United States were composed largely of Pennsyl-

vanian species continuously surviving, with relatively slight modifications, in the same basins. Here the climate certainly was generally mild in the early Permian. In fact, the change in age from Pennsylvanian to Permian is to be detected mainly through the increasing number of species immigrant from the Permian of western Europe, where the contrast between Pennsylvanian and Permian plant life was somewhat stronger.

On the other hand, the so-called cosmopolitan Permian flora of western Europe and of North America soon showed signs of generally less equability and, in particular, of seasonal variation in climate, with clear evidence of deficiency of moisture in many regions. The vegetation was, however, sufficiently voluminous and the rainfall adequate for the development of thick coals in some of the fresh water basins of France and the Appalachian trough. Well-marked seasonal variation in rainfall is, however, clearly indicated by the almost total extinction of the few remaining heterosporous lycopods, by the prevalence of gigantic tree ferns (Psaranius) with enormous inclosed ramenta and by the development, in moderate strength, of annual rings of growth, though the latter are in general not so sharply defined as in the petrified woods from the province of the Gangamopteris flora. The wood cells are generally smaller, the wood growth being apparently slower.

The fern-like plants which compose the greater part of early Permian vegetation were generally rather thick-leaved, and some have xerophytic features. There is little doubt as to the alternately dry seasons which in western North America soon became of probably far greater consequence than in the east. In fact, the western American flora, to which were added a number of migrants, via the Bering land connection, from Korea, south central China and the Ural Mountain region, suggests seasons of semi-aridity or real aridity. Thus the evidence of the vegetation is essentially in accord with the physical records such as the deposition of great thicknesses of gypsum, rock salt and even potash salts in the western mid-continent and southwestern regions of vast tidal flats and evaporation pans more or less filled with red sands, red mud and salts of different kinds, of Permian age. The greater climatic diversity of the Permian accords with the evidence of continental changes, including especially mountain building, with its consequent effect on the distribution of rainfall.

Knowledge of the later Permian floras is everywhere meager, both because of unfavorable life conditions where land deposits were laid down and because progressive uplift of the land was unfavorable to burial of plant débris in sedimentary deposits. Fern-like plants were reduced in variety and appear in general to have been comparatively stunted. The trees were mainly gymnosper-

mous. Most of the early Permanian types had vanished. The later flora was generated under the stimulus of a changing and somewhat inhospitable environment.

It has been noted that many of the early gymnospermous and cycadofilic plants of "Coal Measures," or Pennsylvanian, time were developed in mild equable climates of copious and well-distributed rainfall. The coming of dry seasons, and possibly of irregular periods of deficient rainfall in latest Pennsylvanian and especially in Permian time, led to the ascendancy of the coniferous stock, and to provision for survival of seed vitality through more than one season unfavorable for germination. This was the period of origin and rapid expansion of Walchia, supposed to be the earliest of the Araucarian stock, which was destined to play an important rôle in the Mesozoic flora, and which is now reduced to a few genera practically confined to the southern hemisphere.

Another interesting order of plants, which appears to have had its forerunners in the latest Paleozoic, is that of the living maidenhair tree or Ginkgo. As my colleague in this program will have pointed out, Ginkgo, the varied species of which became amazingly widespread during the Mesozoic periods, is now reduced to the single species with which we are familiar, it having been for centuries nurtured in the Buddhist Temple gardens from which it has been given back to the world.

In the foregoing paragraphs stress has been laid upon the remarkable distribution of the upper Paleozoic floras which are known to have ranged from low temperate zones as far north as terrestrial sediments were laid down—far within the Arctic Circle. Admitting that our knowledge of the Carboniferous floras is mainly confined to the lowlands of fresh water basins and coastal plains, granting that we have little information as to the upland and mountain floras of the time, and even conceding that there were in the same latitudes areas less hospitable in which land-plant-bearing deposits were not laid down or have not yet been discovered, it is nevertheless unmistakably true that the climates during the greater portions of the Upper Devonian and Carboniferous were mild and comparatively equable throughout a large part, at least of the world, and from low to high latitudes. Some minor changes are to be noted in the meridianal direction, but the general composition of the floras is identical to a remarkable degree.

Relative equability and mildness of climate and great latitudinal range of climate in relative uniformity are, geologically speaking, normal. On the other hand, great climatic differentiation and variability, both seasonal and geographic, are abnormal, and are, I believe, confined for the most part to periods of diastrophic revolution, such as that in which we live. The causes of these extremes and

possibly even of Pleistocene glaciation itself lie, according to the writer's views, largely in the geologically abnormal conditions of continental outline and land exposure now in effect, and in the resulting currents and temperatures of air and water.

It will be remembered that the continents of the northern and western hemispheres now stand high; the continental shelves are to a large extent laid bare, thus increasing the areas of land radiation, and the epicontinental seas—great stabilizers of temperature—are largely withdrawn. Meanwhile, the mountain building of the post-Tertiary revolution is still in progress in portions of the continents, and, in general, mountain ranges may be regarded as comparatively near their maximum average in height. Present land configuration and relief are, therefore, from the geological standpoint, abnormal, and, so, abnormally favorable for great climatic variation and the development of climatic extremes. They are conspicuously different from the generally low relief and the configuration of the notably further submerged continents, more broadly decked by warm continental seas, generally characterizing the greater part of geologic time between the episodes of major uplift.

Minor continental deformation or uplifts, with attending changes in shore lines and epicontinental seas have, of course, occurred from time to time during the great periods of relative uniformity and tranquillity of climate. To the needs for adaptation and adjustment imposed by these environmental changes we owe the great stimulus to organic evolution, and the generation of species and genera of greatest value in stratigraphic paleontology. Several of these changes may have occurred within the really great time represented in many instances by a few hundred feet only of deposits now classified within the limits of a single formation, as is well illustrated by the known variation in the history of deposition of the comparatively thin aggregate of materials laid down during Quaternary time.

While the climates covering the great uplifts or periods of revolution may be compared to that of the present day, they were in most cases not so drastically varied and the extremes were by no means so great as now.

THE SPACING OF ICE AGES AND EARLY PRE-CAMBRIAN CLIMATES

By Professor A. P. COLEMAN
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A GENERATION or two ago it was believed that the earth's climates before the Pleistocene were controlled by its own internal

heat. The nebular hypothesis, as usually accepted, made the earth begin as a sphere of gas which slowly cooled and became liquid and afterwards solid. Finally, a temperature was reached when water could exist and in process of time life appeared in the world and historical geology began. The fall of temperature continued through the successive geological ages until the climax of cold was reached in the Ice Age.

This belief was seriously shaken when proofs were found in India and the southern hemisphere that there had been a more severe time of glaciation at the end of the Carboniferous, from which, however, the earth soon recovered completely. It is now known that times of unusual cold have occurred here and there in geological time as far back as the Huronian.

The evidence mainly relied on to prove these ancient depressions of temperature is the finding of peculiarly shaped stones having scratches on their surfaces. Usually these are enclosed in unstratified clayey material, called boulder clay or till; and when a till is consolidated to rock it receives the name "tillite." These "striated stones" or "soled boulders" are articles manufactured only by ice. No other geological process can make them; so that the finding of typical striated stones is positive proof that a glacier was at work.

Such stones are to be found everywhere in the till of the last ice age and in earlier glacial deposits of different ages, such as the Permo-Carboniferous, the early Cambrian and the Huronian. It is found, however, that wherever these rocks have been squeezed and crushed in mountain building the polish and striae of the pebbles disappear and the tillite may even be changed into a schist so that the proofs of ice work are lost altogether.

Comparatively unchanged sedimentary rocks in which striated stones could be preserved have been found at one point or another in various geological formations down to the Huronian; but all the sedimentary rocks below the Huronian have been so much metamorphosed that it is hopeless to look for striated stones in them.

Are we to assume that no glaciation occurred in the next lower series of rocks, the Timiskamian; or in the lowest of all, the Keewatin, because no striated stones have been found in the boulder conglomerates which occur in both of them?

The Timiskaming sediments are well enough preserved in some places, as at Sudbury, to show much of their original structure, and it is found that thousands of feet are banded with coarse and fine layers an inch or two thick, just like the "varve" clays deposited in lakes in front of the ice in the glacial period. It is certain that there were seasons when the Sudbury beds were laid down, probably cold winters and warm summers. This suggests that the boul-

dery rocks of the same formation may have had a glacial origin in spite of the absence of striated stones.

The older Keewatin Series has been too much deformed in mountain building to supply even this evidence of its climates.

While absolute proof of glaciation may never be found in the most ancient series of rocks, there is one line of evidence strongly suggesting that the thick boulder conglomerates which occur in them were made by ice, like the tillites of later times.

The spacing of ice ages in the better known parts of geological time is peculiar and decidedly interesting. If we run down the table of formations we find that glaciation occurs more frequently in the earlier divisions than in the later ones, just reversing the view once held by geologists. Before the last ice age no important glaciation is known in the Cenozoic, and the same is true of the whole of the Mesozoic; while the two most severe ice ages on record, that at the end of the Carboniferous and that at the beginning of the Cambrian, belong to the Paleozoic, and some glaciation has been reported from all its major subdivisions except the Mississippian.

Much the same is true of the upper pre-Cambrian, and there must have been an important lowering of temperature to produce the many thousands of square miles of ice sheet known to have spread out over the Canadian Shield in Huronian times.

We are sure that liquid water was at work when the earliest known rocks were formed, since they include undoubted sediments; and from the evidence just given, showing that glaciation was more common in earlier than in later times, it is very probable that even in the Keewatin water took on the solid form and glaciers transported the boulders found in the coarse conglomerates of that age.

It may be remarked in conclusion that since periods of cool or even of cold climate are on record at a number of points in the history of the world, reaching back to the most ancient times, there is no geological evidence that the surface of the earth was ever hot.

If the earth began as an intensely hot nebular mass it must have completely cooled down before the earliest known rocks were formed; and the nebular stage, if it ever existed, has little direct interest for the geologist.

THE SOLAR-CYCLONIC HYPOTHESIS AND THE GLACIAL PERIOD

By Professor STEPHEN SARGENT VISHER
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EXPLANATIONS of changes of climate such as the glacial periods indicate have been numerous. Three historically important hypotheses may be briefly stated. (1) According to the elevation

hypothesis, the continents during the glacial periods were much more elevated than now, high enough so that the glaciated portions corresponded with the snow-covered mountain tops of to-day. (2) The possibility that the *poles* may have wandered sufficiently so that the ancient glaciated areas, southern Illinois, for example, were subpolar, has been repeatedly suggested. (3) According to the much more carefully developed hypothesis of Chamberlin, the atmospheric composition and the oceanic circulation have varied from time to time in such a way as to produce radical changes of climate. Other writers have attempted to explain changes of climate by assuming variations in the ellipticity of the earth's orbit, in the amount of heat given out by the sun, in the distribution of land and water and in the intensity of volcanic activity.

Most of these theories were developed before a large body of facts relating to ancient climates was available, or else were offered by persons not familiar with the geologic evidence. When they are tested by the facts now known as to the irregular distribution of the ice sheets of the last great ice age, the alternation of glacial with mild interglacial epochs, and the contrasts among the several glacial epochs, they are seen to be inadequate. By far the best is Chamberlin's, but that hypothesis is unable to account for the more sudden climatic changes indicated by repeated pauses in the retreat of the ice sheets (shown by the recessional moraines), or for the irregularity and certain other features of the mild interglacial periods. Professor Chamberlin himself admits the inadequacy of his theory in these regards.

In 1914, Ellsworth Huntington, of Yale University, turned his attention to the possible causes for these changes. He recognized that there has been insufficient change in the altitude of the continents, in the distribution of land and water, or in the position of the poles to cause the observed climatic changes. The length of time between the changes was, in many cases, altogether too short to warrant the assumption that there had been a significant change in either the percentage of carbon dioxide in the atmosphere, or in the direction of the oceanic circulation. Hence he began to consider the possible terrestrial effects of solar changes. A "solar hypothesis," that variations in the amount of heat emitted by the sun produce the observed climatic changes on the earth, had been advanced long before by Blanford, Lockyer and others, but it did not seem satisfactory, because a mere variation in the amount of heat apparently could not account for the complex changes of terrestrial climate.

The possible climatic significance of variations in storminess occurred to Dr. Huntington. The reason for this was that his

studies had led him to conclude that only slight changes in mean temperature have occurred during the last 3,000 years, whereas fairly large changes of rainfall appear to have taken place. The rainfall in the eastern Mediterranean lands and Central Asia, where the chief evidence of climatic fluctuations in historic times has been found, is almost wholly cyclonic. Therefore the best way to account for its variations seems to be by changes in the number, intensity and paths of cyclonic storms. Searching about for discussions of this subject, he found that cyclonic storms had been almost entirely ignored by writers on climatic changes. Nevertheless, a consideration of their probable climatic importance and some evidence of their variation at such periods as the fourteenth century led him to suspect that they were important factors in glacial as well as historic fluctuations.

The solar-cyclonic hypothesis has two phases: (1) that variations in storminess produce important changes of climate, and (2) that solar changes somehow lead to changes in storminess. The effective focussing of attention upon the climatic significance of cyclonic storms is a contribution of high value to the discussion of causes of climatic changes. This is illustrated by the fact that such opposed investigators as Humphreys and Chamberlin, who formerly ignored storms, now make large use of them in their modified theories. They are convinced that storminess is important. Some of the effects of increased storms in any particular region are (1) the cooling due to increased cloudiness, precipitation and winds, (2) differences in the distribution of precipitation and (3) increased evaporation and precipitation resulting from increased wind velocity. A fourth effect is the influence of storms upon the northeastward movement of warm waters in the Gulf Stream Drift and similar currents.

The second phase of the solar-cyclonic hypothesis is that solar changes produce changes in terrestrial storminess, and that if the changes of storminess observed during a sunspot cycle to-day were intensified and magnified sufficiently in the past, some of the aspects of ancient climates which have hitherto been inadequately explained would have been produced. Conditions during a sunspot maximum are of the glacial type and those of the sunspot minimum of the interglacial type. During a sunspot minimum storminess decreases, at least in high latitudes. If, during certain epochs in the past, there were almost no storms, climatic conditions would have been notably different in certain large regions. For example, most of the United States east of the western mountains would be arid because then the westerly winds would prevail, and such winds would lose their moisture in crossing the western

mountains. The rain and snow of the eastern half of North America are practically all brought from the Gulf of Mexico, and precipitated by cyclonic storms. If there were no storms, and hence no precipitation, there could be no glaciation in eastern North America. Hence, if during the glacial period, storminess for some reason decreased greatly or disappeared, the glaciers covering much of northeastern North America would necessarily promptly diminish from lack of snowfall and an interglacial epoch would be inaugurated. In northwestern Europe, on the other hand, a decrease in storminess would mean a greater warming in winter because of the stronger southwesterly winds and the associated more rapid movement toward Europe of the warm waters of the Gulf Stream Drift. The European glaciers would disappear during an interglacial epoch therefore by melting rather than by evaporation.

Changes in storminess will not explain all the facts of ancient climate. Changes in land elevation and distribution, in the composition of the atmosphere and ocean, and in the direction of the oceanic circulation are also important. Furthermore, other agencies may have helped produce the numerous complex changes of climate or aspects of climate revealed by the geological record. Nevertheless, the solar-cyclonic hypothesis has effectively pointed out the climatic importance of cyclonic storms and hence of changes in storminess, it has offered a plausible explanation for certain hitherto inadequately explained phenomena, including the suddenness of some of the minor climatic changes and the occurrence of mild interglacial epochs in the midst of a glacial period, and it has stimulated further study of the subject of ancient climates and climatic changes by bringing a new and helpful factor into the field.

CAN WE EXPLAIN GRAVITATION?

By WALTER D. LAMBERT

U. S. COAST AND GEODETIC SURVEY

Sir Isaac Newton did not discover the force of gravitation. Multitudes before his time had seen apples fall and had noted that falling to earth is the regular habit of inert unsupported bodies. Long before Newton, scholars had generalized these results of observation into the statement that bodies are attracted towards the center of the earth. What the fall of the apple did—if we accept this somewhat apocryphal tale—was to stimulate Newton to consider whether the attractive force might not extend beyond the earth far enough to govern the motions of the earth's nearest neighbor, the moon. His calculation showed that, if terrestrial gravity were conceived as varying inversely as the square of the distance from the earth's center, it would explain the motion of the moon around the earth and that a similar force would explain the motion of the earth and of the other planets about the sun. The patient studies of the elder Herschel on double stars showed, as had been anticipated, that the same kind of force appeared to govern their motions also.

Just because the effects of gravitation are so familiar and because Newton's law accounts so completely for the motions of the heavenly bodies, except for a few minute effects which Einstein's theory represents better than Newton's, we are apt to forget how mysterious gravitation is and how little our so-called explanations penetrate the mystery.

Between ordinary objects the attraction of gravitation is very small, between bodies of astronomical dimensions very great, in spite of the immense distances that usually separate the latter. Suppose, on the one hand, two spheres, each one inch in diameter and made of osmium, which is the heaviest known metal, being twice as heavy as lead, and suppose them to be placed at rest two feet apart. Under the influence of their mutual gravitational attraction and with all resistance to their motion absent, it will take about one day and five hours for them to come into contact. To those not familiar with the cumulative results of very small forces working unopposed over considerable periods the time required for the two balls to come together may give a very inadequate idea of the minuteness of the force. When the balls are two feet apart, the force between them is 0.000 000 67 dyne. An illustration will give some idea of just how small this is. Take the metal in an ordi-

nary silver dime, which weighs $2\frac{1}{2}$ grams, or less than one tenth of an ounce, and draw it out into wire fine enough to extend all the way around the earth. The force between the two spheres of osmium referred to above will be less than the weight of one half inch of this fine wire.

On the other hand, between bodies of astronomical dimensions the forces are almost incredibly large. If the gravitational pull of the sun on the earth, which is the force that maintains the latter in its orbit, were to be exerted by means of a cable having the tensile strength of ordinary structural steel, in order barely to escape rupture the diameter of the cable would have to be about three quarters the diameter of the earth. This calculation supposes the material in the cable itself to be destitute of all power of attraction, either on itself or on other bodies. If the cable were of ordinary attracting matter, the stresses would be enormously greater, quite beyond the power of any known material to sustain.

The force of gravitation differs from all other known forces. It is not affected by the motion of the attracting bodies, as electrical forces are. It is not dependent on the nature of the attracting matter, only on its mass and position. Efforts to detect a change in attraction corresponding to changes in temperature have failed.[1] Gravitation appears to be transmitted instantaneously to all distances and not to be screened off in any way by the interposition of matter of any kind.

What do we mean by an explanation of physical phenomena like those of gravitation? Our so-called physical explanations are almost always mere descriptions of one sort or another and do not attempt to elucidate the "ultimate whereforeness of the thusly." The description may be a mathematical rule that can be applied to deduce certain conclusions. If these conclusions are found to be in accord with observation, we say that the explanation is a good one, so far as it goes, and the wider the range of observation facts embraced and the more diverse they are, the more satisfactory do we consider the explanation. Such is Newton's law of gravitation. It is a mathematical process that can be used to predict with great accuracy the complex movements of the moon, planets and stars. Where it has appeared to fail slightly, a more rigorous examination has almost always shown the mathematical analysis and not the law to be at fault. The chief exception is the famous question of the perihelion of Mercury's orbit. So far, all

[1] Theoretical considerations brought forward by Einstein, but not necessarily dependent on his theories of relativity and gravitation, indicate a very small decrease of attraction with temperature, much too small to be detected by present means.

attempts to explain completely the motion of the perihelion by Newton's law have been unsuccessful, unless suppositions are made that would imply serious perturbations in the motion of other planets, perturbations which are not verified by observation. It is one of the triumphs of Einstein's theory that it succeeded where Newton's failed.

But a mere mathematical formulation, however comprehensive it may be, however many diverse consequences it may contain implicitly packed away in a few brief general statements, and however closely those consequences may correspond to experience, does not by itself completely satisfy our minds. We like a working model of our law, something analogous, though perhaps on a molecular scale of magnitude, even an atomic or electronic scale, to the mechanisms of every-day life. We like to see the wheels go round. In this respect the explanations of both Newton and Einstein fail to satisfy. They give a basis of calculation but they do not illustrate. To transmit the vibrations of light and electricity, physicists imagined the ether, but to make it perform satisfactorily they had to endow it with properties very different in degree from those of any known material. But what medium shall we conceive that will transmit gravitation instantaneously to all distances, unaffected by the physical state of the attracting bodies or by any interposed matter?

The difficulties of constructing, mentally, a working model of gravitational attraction according to Einstein's law are quite as great. Einstein makes gravitation a property of a certain non-Euclidean space of four dimensions, one dimension of which is imaginary time, and this imaginary time is assumed to be indistinguishable in kind from the other dimensions.[3]

We have been thinking so long in terms of the Euclidean geometry that we find it nearly, if not quite, impossible really to visualize non-Euclidean space even of three dimensions. The so-called four-dimensional geometry is merely mathematical analysis with four variables, analysis having certain analogies with an analysis of three variables that can be interpreted geometrically in terms of three-dimensional space. It thus seems natural to use geometrical language in connection with our calculations on four variables, but when all is said and done, it is really analysis that we have

[3] This idea of time as a fourth dimension did not originate with Einstein. It was put to practical use in obtaining solutions of certain differential equations of mathematical physics by the late R. A. Harris, of the U. S. Coast and Geodetic Survey, and by Professor Whittaker, of Edinburgh. This was merely a mathematical device, justified by its results, and was not made the basis of any general physical—or metaphysical—theory.

and not geometry as the ordinary person understands it. What with the non-Euclidean nature of the space and the added dimension, the task of obtaining a mental picture of the workings of gravitation is difficult indeed. It is even maintained that, properly to state the matter in Euclidean terms, ten dimensions are necessary.

Neither Newton's nor Einstein's theory gives us a working model of gravitation Both of their theories are in effect simply rules of calculation, although—to be fair to Einstein—it should be said that the development of his theories required, in addition to great mathematical skill and knowledge, a wide acquaintance with the results of experimental and theoretical physics and a familiarity with that region of thought where physics merges into metaphysics. Einstein's rule gives, in most cases, results substantially the same as Newton's, although, where they differ by amounts accessible to observation, the results of the Einstein theory accord better with experience than do the results of Newton's. Einstein's theory embraces a wider range of phenomena and, on this account also, should be given the preference. But it requires much more complicated calculations than Newton's theory, and its basis is much more remote from our ordinary ways of thinking than even Newton's mysterious force, so remote that the statement of it easily runs into paradox. But the paradox is not entirely due to Einstein or his expositors. In some respects nature herself seems to play the paradoxer. It is doubtless this seemingly paradoxical quality that has aroused the popular interest in it. Generally the man in the street concerns himself not at all with an abstruse scientific theory, but when the air resounds with the dispute between the adherents of the older and the newer theories and paradoxical statements fly thick and fast, the man in the street looks on with a real, though puzzled, interest.

Einstein's theory, however, is so successful as a basis of calculation that there "must be something in it" but just what that "something" is we do not clearly see. Perhaps we may get used to thinking in Einsteinian relativistic terms, or perhaps some more general form of statement will be found which will include those parts of the Einstein theory that are valuable as a basis of calculation and which will, at the same time, be expressible more nearly in terms of our present, every-day ideas of time, space and force. Meanwhile, we can merely calculate and describe the effects of gravitation, but we can not really explain it. But, if and when that time comes, will the new "explanation" be anything more than a description, a description perhaps in terms more exact, more compact, more familiar or more comprehensive, but still only a description?

THE COLUMBIAN GROUND SQUIRREL AS A HANDLER OF EARTH

By WILLIAM T. SHAW
WASHINGTON EXPERIMENT STATION[1]

LIVING in tunnels which he himself excavates in the earth, it is not surprising that the Columbian ground squirrel (*Citellus columbianus columbianus*) has reached considerable skill as a handler of soil. My attention was first attracted to his capable methods of doing this while making quiet observations upon this squirrel in observation yards which had been constructed for its close study.

These exhibitions were generally given at the entrance of a burrow where a mound was being piled. Frequently a squirrel would appear at the mouth of one of these holes looking somewhat ruffled, and progressing backwards with his burden of earth. In handling it he would proceed after this fashion Placing his hind legs firmly and widely apart, he would dig very rapidly with the front feet, packing the loose dirt up under his belly. Then he would kick it back with his hind feet, alternately right and left, quite rapidly, though not so quickly as with the front feet At this time one would see a shower of earth being shot swiftly to the rear, and the body of the squirrel sink simultaneously into the trough under him, made by this displacement. Not infrequently, after the earth had accumulated into a considerable heap behind him, he would turn and ram through the mound, with his nose, plowing the loose dirt ahead, soon emerging with the short stiff hairs of his face bristling with earth particles

Of course to observe his methods of handling soil in the depths of his den was more difficult. On March 10, 1917, we had a good opportunity of observing this while digging for a recently awakened hibernating squirrel. He had escaped from the nest into the drain and was digging rapidly in an effort to escape. He would dig with a very rapid movement of his front paws, sometimes bracing his shoulders against the walls of the burrow and digging sidewise, much like a dog will do when after some large burrowing animal. When considerable earth had been loosened and became too much in the way, he would turn about in his cramped quarters and ram it back with his nose, thus firmly plugging the passage behind him.

In making the tunnels in the dens it is probable that not all the earth is brought to the surface, but is deposited in some unused

[1] Published with the approval of the director of the Washington Experiment Station, as Scientific Paper, No. 119, College of Agriculture and Experiment Station, Pullman, Washington.

Photo by William T Shaw

FIG 1 FILLED HIBERNATION CELL

In the dens of ground squirrels it was not unusual to find old hibernation cells, burrows, and drains, compactly filled and tamped with earth, so solidly placed that it could be excavated and still remain as a mass

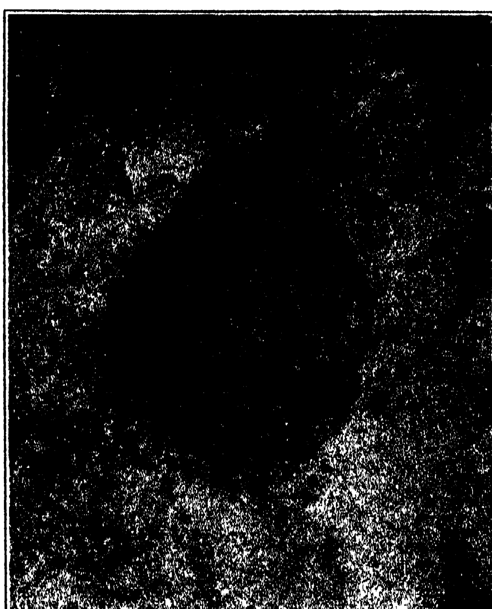

Photo by William T Shaw

FIG. 2. A PLUGGED BURROW

Oftentimes in excavating squirrel dens, it was found that many of the burrows were plugged with earth. The illustration shows one of these at a point where the work of plugging ceased. The pits, looking like finger tip depressions, are made in the soft earth by the nose of the squirrel in tamping.

burrow, nest-cavity or cell (Fig. 1). Many of the holes which appear on the surface of the ground without any fresh earth about them may be accounted for in this way, they having been excavated from below Indeed it would seem that they are all originally made in this way

It is very noticeable that much of the digging of earth is done in the spring and early summer when the ground is still soft. It has also been observed that much earth is thrown out of the dens after rain showers, as if the squirrels employed themselves in this way when the weather would not permit of their being outside On May 8, it was noted that five holes out of eight in a den had fresh dirt thrown out of them from the burrows within an hour after a shower

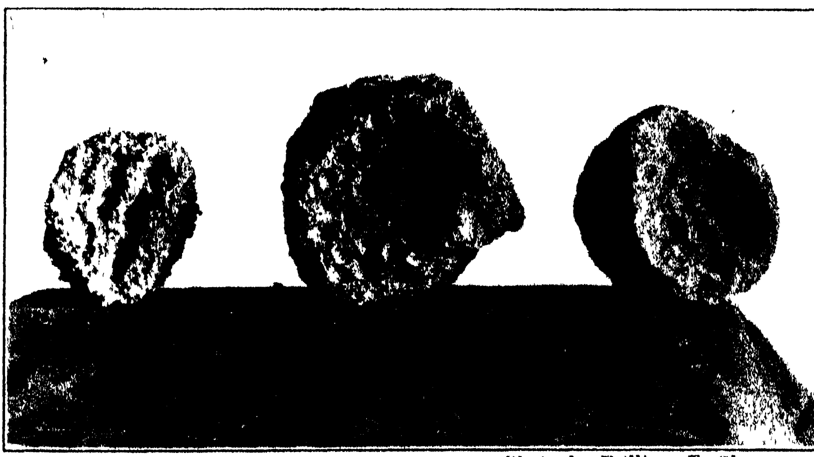

Photo by William T Shaw

FIG 3. TYPES OF PLUGS

In this illustration three types of plugs are used On the left is a plug made when the earth is moist and soft, allowing the impression to be made much deeper. To the right is a closing in plug taken from a hibernation den, where of necessity dry earth of the season had to be used The plug in the center made from medium moist earth is a typical example of this kind of work, showing clearly the nose prints of the worker.

They seem to be methodical in their operations, as it was noted that three captive male squirrels in the yards completed the excavations for a den in their yard and, having this finished, suddenly transferred their nest from the box thereto.

But a much more remarkable use they have developed for disposing of loose earth in their burrows is found in the plugs which they construct within the burrows themselves at various depths and at different places. Early in the investigation of the dens of this squirrel, by the writer, at Pullman, Washington, it was noticed that the burrows were in many cases plugged and ob-

structed with earth (Fig 2). At first it was thought that this was due to water washing soil down into the holes, or that it might have been due to the work of the pocket gopher, an animal frequently inhabiting unused squirrel dens. These plugs were, however, rather too solid to be made in either of these ways, being so firm that they could be completely excavated from the tunnels in which they were placed (Figs 3 and 8) There was a regularity in which they broke into disk-shaped layers (Fig 4). They were pitted on the concave side and covered with corresponding elevations on the convex It was concluded that this was done by pressing the moist earth into place with the nose as is done by the prairie dog [1] As these plugs were found constantly both in the summer dens as permanent structures (Fig. 5) and in the hibernation dens as temporary obstructions (Figs 6 A, 7), it is proposed to consider them at some length

One reason for this plugging is protection Here the cavity of a brood nest may be protected by having one or more of its entrances closed by this peculiar sort of squirrel masonry. A second use of the plug is in reconstruction of a hibernation cell where only one entrance is needed A further use of the plug, especially the temporary plug described below, is to close the entrance of the burrow in order to keep out cold or a threatening present danger.

It is not uncommon to see these plugged burrows exposed in newly made road cuts or basement excavations, even in the center

Photo by William T Shaw

FIG 4. SAUCER-LIKE LAYERS OF A PLUG

Each quotum of earth as it is brought to the scene of burrow plugging is tamped firmly against the preceding one. By careful effort these may be broken apart, showing nose pits on their concave and corresponding elevations on their convex sides.

[1] Merriam, Yearbook, United States Department of Agriculture, 1901, p. 260.

Photo by William T Shaw

FIG. 5 RECONSTRUCTION OF DENS

The nest cavity on the right is now guarded from approach by the plugging of the two burrows leading to it; the one under the handle of the knife and the other at its tip. In this way the nest cavity is made much more safe

of the town They frequently look as fresh as the day they were made.

It is almost never done outside of the den, as it is in the case of the prairie dog. Only once have I noticed this A squirrel, supposedly digging, was observed Wishing to see what sort of bulb it was after I frightened it away Strange, but the supposedly digging squirrel, which reluctantly left its task, was found to have been tamping the moist dirt down into a pitted saucer. It was plainly the work of the nose On digging to see what it had buried, I found, about three inches down, a large open burrow. This burrow had come up from the inside into the middle of a cow path, and fearing disturbance, the squirrel had plugged it from the inside first and then had undertaken to make the job more complete by tamping it on the outside. The inside of the plug was concave and showed signs of nose prints. Of course to observe the operation below in the dens was difficult. Generally, however, there is enough loose earth in the bottom of a burrow to furnish material for a hastily constructed plug in case of pursuit.

In the spring of 1914, while working on the extermination of the ground squirrel with gas, we not infrequently came upon short temporary plugs inserted in various places in the burrows (Fig. 6, A). These plugs were placed in the burrow chiefly to prevent the cold air of the chill spring evening from entering.

This form of plugging was noticed on February 26, in a den on a cold north slope On the 27th about 3·30 P. M. we went to dig out the den Down the exit shaft about a foot we came upon a soft earthen plug obstructing the passage The squirrel had dug a little pocket in the side of the burrow where it is supposed it got the earth for the plug, as the soils in the pockets and the plug were the same This may account for the formation of the turning pocket, a small cup in the side of the burrow where they turn to reappear again at the mouth of the burrow after having been frightened in The plug itself was quite firm and showed signs of nose prints where it was packed in concavely from below

Again on March 5, a workman saw a squirrel enter a hibernation exit. To make sure it would not escape he placed a board over the hole An hour later the den was treated with carbon bisulphide We were later surprised to find the squirrel had put in a short plug two feet eleven inches below the entrance, just above the nest entrance

On March 6, a hibernation exit was found and a straw placed across its entrance to tell if the den were still inhabited. The following morning on examining this exit it was found that it had been plugged from the inside, the fresh dirt being pushed up until it just touched the straw. It was left as it was for observations and by eleven o'clock in the morning the hole had been opened. The squirrel, a female, was afterwards killed by carbon bisulphide. At least six cases were found in the fields and yards

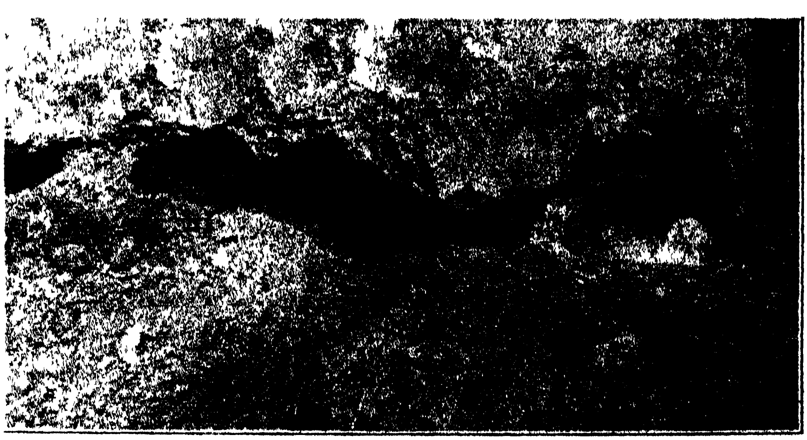

Photo by William T. Shaw

FIG. 6. A TEMPORARY PLUG

In the spring when the air is still cold the squirrel closes the entrance to his nest by tamping in a temporary plug which may be located at various places in the shaft leading from the nest to the exterior Such a plug is shown at A.

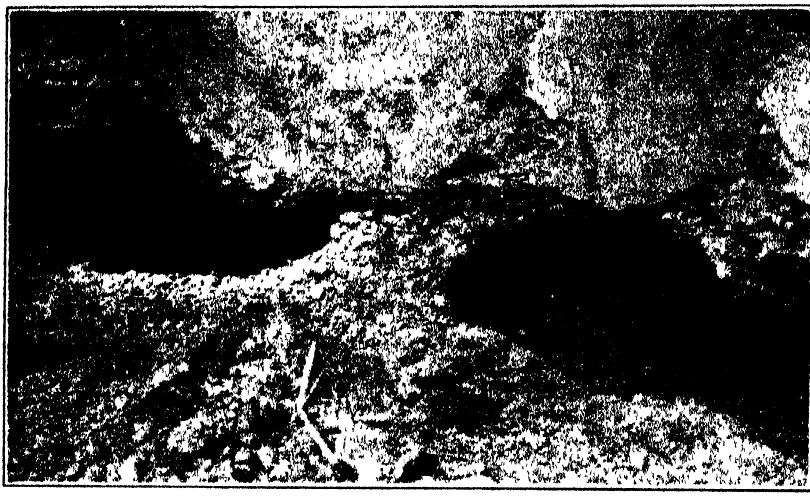

Photo by William T Shaw

FIG. 7 TEMPORARY PLUG

This figure gives a close view of the plug shown at A in Fig 6 On the right side, next to the nest, the nose prints can be plainly seen The plug is about three inches thick.

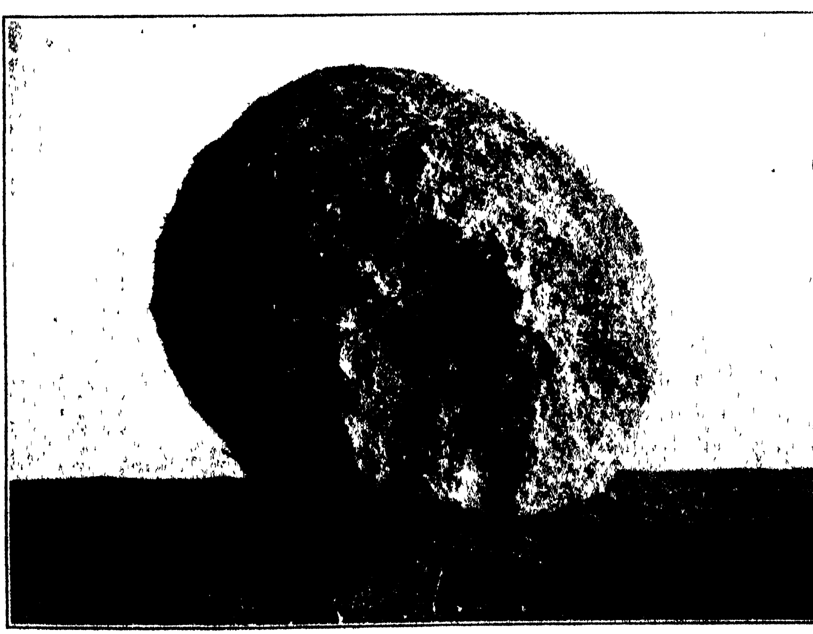

Photo by William T. Shaw

FIG. 8. A CELL PLUG

This plug, taken from a hibernation cell, is hard and durable, even resisting the light stroke of the pick when being broken. Nose prints in the center of the figure show clearly where the work ceased at the neck of the cell.

With these and subsequent observations in mind, it is thought that the temporary plugs are chiefly used in the early spring, as they were not noticed in the burrows later in the summer. On cold days there is not much activity among these recently awakened squirrels On March 1, a cold wind springing up during the afternoon (Temp 37 degrees F) caused the squirrels to put plugs in the exit shafts An exit was found and a straw placed across it in the forenoon In the afternoon of the same day the squirrel had not left the den but had put in a plug below the straw. That they use the plug for protection seems probable One late afternoon I saw a squirrel disappear from the perfectly plane surface of a field. I walked at once to the spot and found an exit. In the very short interval of time it had put in a small plug, which came about an inch below the surface Was this plug to ward off danger or to keep out the cold of the approaching night? A similar instance was observed on March 3, a bright warm morning. A large squirrel was seen standing in the erect, watching position, halfway across a 20 acre field As I approached it ran and disappeared in a hibernation exit which had about one third of its diameter plugged from the inside This plugging was done on a sunny morning and would indicate that the plug was a protection against an approaching enemy

It was later found that two plugs are sometimes used in the same exit shaft In the spring of 1917, an exit was observed on March 6, and on the 8th it was stopped by a soft earth plug placed within an inch of the ground surface. The day was raw and a little wind blowing On the 10th we went to examine this den and found it still plugged The plug was dried on top as though it had not been disturbed since the 8th. We opened the plug and ran a cane down full length at an angle of 45 degrees. On digging we broke into the exit shaft and about 30 inches below the first plug found a second one This plug was placed like other temporary plugs, and was about 3 inches thick. Occasionally this tendency to plug was shown about the boxes in the observation yards.

When considering the nature of their habitat, it is not surprising that they have become skilful and resourceful in the use of the material at hand, as have other rodents such as beavers, with the material of their environment.

CHROMOSOMES, ENDOCRINES AND HEREDITY

By Dr. CHAS. B. DAVENPORT

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COLD SPRING HARBOR, N. Y.

THE word "heredity" has had various connotations at different times Very early it was recognized that the children are the heirs of certain traits of the father and mother and hence arose the primitive conception of heredity Studies of genetics during the past quarter of a century have established the idea that what is inherited is not the visible traits of the parents (the phenotype), but the genes of such, which are carried in the germ cells (the genotype) With the recognition of the importance of the genotype in heredity attention has been directed to the genes themselves as they are located in the germ cells, and during the last fifteen years there has developed a new conception of the rôle of the chromosomes as carriers of these genes On the one hand, through the remarkable studies of T H Morgan and his associates, the architecture of the chromosomes is being determined in detail so that maps can be drawn indicating graphically the relative linear position of these genes in the chromosome An example of such a chromosome map is shown in Figure 1, which indicates the relative position in the first chromosome of the genes responsible for a large number of mutations which have been found in the banana fly, *Drosophila virilis* Whenever a particular abnormality appears in the eyes, wings or body of this insect, a corresponding change apparently has occurred in the material occupying a particular point in the particular chromosome in which is located the material chiefly responsible for the production of that abnormality This discovery marked so great an advance in our knowledge of heredity that it is not strange that in his enthusiasm the principal investigator in this field should have exclaimed· "The problem of heredity is solved!"

However, it has not been possible to explain all mutations on the ground of the modifications of the genes lying in the chromosomes. On the contrary a series of mutations have been worked out, chiefly by A. F. Blakeslee and John Belling, which depend upon modifications in the number of entire chromosomes. In the Jimson weed, *Datura stramonium,* which has normally 12 sets of chromosomes, 2 in each set, the 12 pairs of chromosomes obviously carry, like the different chromosomes of the Drosophila, each its special

genes. These chromosomes differ thus in structure as indeed they do in size so that we can recognize chromosomes a, b, c and so on. Now if the chromosome "Set a" comprises, as it occasionally does, 3 chromosomes instead of 2, there is a corresponding difference in the form of the Jimson weed. If "Set b" has the extra chromosome, still a different form of plant results If "Set c" is the one that has the additional number still another form and so on By the addition of one extra chromosome to each of the 12 sets we may have produced, in turn, 12 different kinds of Jimson weeds. In rare cases 2 extra chromosomes may be added to each of 2 of the sets and thus a new set of modifications of form may be brought about, or a chromosome may be subtracted from one of the sets or may be subtracted from one and added to another set Again all the sets may be represented by one chromosome only instead of 2 each. Or all the sets may include 3 chromosomes or 4 chromosomes These are possibilities which permit the plant to survive. Many others are thinkable which probably may cause an early death of the plant In Figure 2 we have a diagram taken from Blakeslee's work, showing some of the different types of variations in the chromosome number; and corresponding differences in form of seed-capsules of the plant.

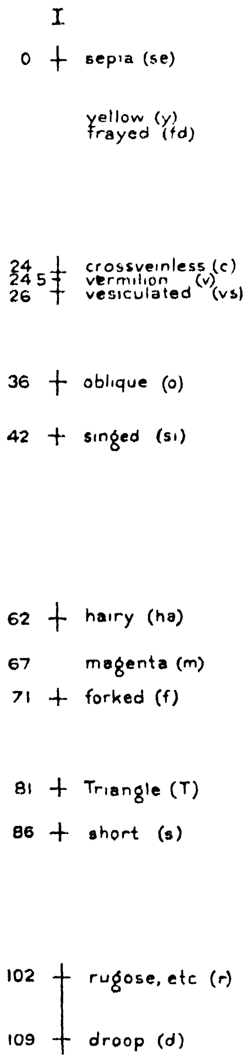

FIG 1
CHROMOSOME MAP
of sex chromosomes of *Drosophila virilis* (Dr C W. Metz)

The relation between structure of the chromosomes—of mutations in its constituent genes, on the one hand, and, on the other, the relation of variations in the number of whole chromosomes or fragments of them, to mutations, seems to justify the conclusion to which the man in the street comes in contemplating the findings of the geneticist, namely, "We are what our chromosomes make us."

The findings of the geneticist are further supported by the similar observation of resemblances between different members of a family. This resemblance is frequently striking among brothers and sisters of one

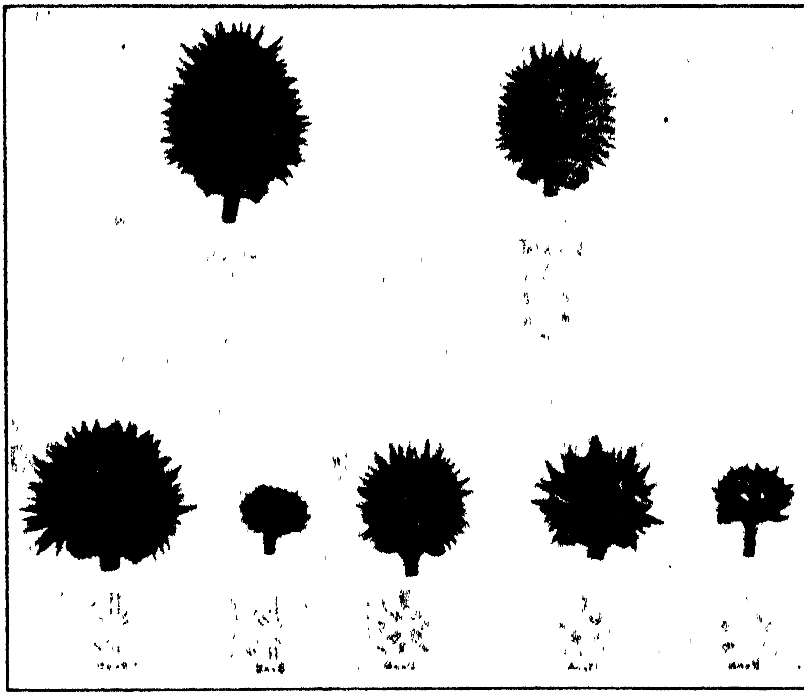

FIG. 2. CAPSULES OF FIVE GLOBE MUTANTS
and corresponding chromosomal complexes (Dr A. F Blakeslee)

fraternity. That it is not more striking—that brothers and sisters so often show points of difference—is due to the fact that the germ cells of the father and of the mother are not at all alike, but may be very diverse, just because of the hybrid nature of their ancestors

There is one phenomenon, however, of striking similarity which has long been noticed and this is the phenomenon of identical twins. Here we have pairs of persons who resemble each other so closely in form and features, in behavior, in resistance to disease, that they are frequently almost indistinguishable. Even their own parents may confuse them Example of such pairs of twins are shown in Figure 3 Now this great resemblance of identical twins is commonly explained on the ground that they are derived from one and the same egg which has produced by budding upon its surface two embryos in the place of one. This view is supported by the fact, among others, of a certain peculiarity of identical twins that distinguishes them from other twins in that the embryos at birth are enveloped in the same envelope, called chorion, whereas in ordinary twins there are two distinct chorions. Since such twins are derived from the same egg and hence from identically the same chromosomes, the view that the chromosomes are the basis of familial similarity is supported. It is, indeed, a

natural extension of this finding that we should ascribe not only family but also racial resemblances to identity of genes which determine the production of these racial characters. Individual differences, on the other hand, are due to mutations in genes of minor importance Family resemblance and racial resemblance depend on similarity of chromosome composition Resemblance is proof of "blood" relationship, more strictly chromosomal identity.

There is, however, another set of facts which must not be neglected In an institution for the feeble-minded one may see a number of persons having a striking similarity which enables us to say at sight that they are cretins A photograph of several such cretins is reproduced, Figure 4 Resemblance between them is often, in general, as great as that between members of the same European race and individuals who do not belong to the same family may be as alike as two brothers In the case of cretins the peculiar and differentiating characters that they show are generally ascribed to the fact of an endocrine disturbance. Their thyroid glands are not functioning normally and hence the similar peculiarities in form that they show.

Still another class of defectives shows an even greater resemblance This is the class of mongoloids, so called from their resemblance in features and bodily proportions to the Southern

FIG 3. FOUR PAIRS OF TWINS
(White Studios, N. Y. City)

FIG. 4. THREE YOUNG CRETINS, UNTREATED

Chinese Figure 5 is a photograph of three such The resemblance between these people is often very marked, so much so that the matron in a building where several of them reside and who sees them very frequently, almost constantly every day, states that she frequently confuses them This is the same sort of resemblance that is exhibited by identical twins, the resemblance which has been used by Galton and others as the strongest evidence for the superior influence on development of nature over nurture. Yet two of the mongoloids in question belong to different European races. Children of Northern Europe and Southern Europe may be almost indistinguishable. The cause of mongoloidism has not been ascertained It is probably due to some endocrine disturbance in the mother, since the defect is already shown in the children at birth. Whatever the abnormal condition in the mother of these mongoloids it is probably normal for the mothers of the typical Southern Chinese, for in almost every respect, excepting intelligence, the resemblance between the mongoloid dwarfs and Southern Chinese is very close. A consideration of the facts of cretins, mongoloids and other types of the feeble-minded whose later developmental impulses, of endocrine origin, are evidently abnormal might indeed lead to the conclusion that "we are what our endocrine glands make us."

The tremendous importance of endocrine glands in controlling the later development of organisms has been brought home to us by the studies of the last two decades. It is known that the transformation of the tadpole into the frog is effected only in the presence of the thyroid gland in the tadpole. For if this gland is removed, metamorphosis fails to occur though growth continues. Again the pigmentation of the young amphibian depends upon the

FIG 5. PROFILES OF THREE MONGOLOID IMBECILES
Of two different racial stocks, left Scotch, middle and right, Russian Jewish

secretions of the pituitary gland, since when this is removed the animals are albinic In humans, also, special disfunctioning of the pituitary gland leads to excessive growth in length of the legs, on the one hand, or to excessive obesity, on the other. Unquestionably the secretions of some of the endocrine glands have a most important effect upon the metabolism on which development depends It is no wonder that the endocrinologist finds in the hormones the principal agency of family resemblance

How can the difference between the views of the geneticist and the chromosomologist, on the one hand, and the endocrinologist, on the other, be reconciled? It would appear that both views can not be true, provided they are mutually exclusive If the chromosomes are alone responsible for resemblance then the endocrinologists must be deceived in their conclusion If the hormones are alone responsible for resemblances then there must be something false in the scientific methods of the geneticist. Either of these conclusions is, however, untenable since both the students of chromosomes and of hormones have worked by the best of scientific methods so that their results are unassailable. Hence we must consider both views to be true and that the chromosomes and the hormones each have their rôle to play in the direction of development The most tenable hypothesis of the nature of the chromosomes is indeed that they are packages of enzymes which activate the metabolic processes of the early stages of development, just as the hormones of the endocrine glands control metabolism in later stages. The hypothesis may be suggested that the chromosomes direct the early stages of development and create certain centers of chemical activity to which they hand over the business of differentiation of particular parts. Thus

the chromosomes may work indirectly in establishing certain centers of later chemical activity whose course they have determined, but in the working of whose mechanism they subsequently do not interfere. The endocrine glands of vertebrates represent perhaps a still later and highly specialized stage in the series of regulators of metabolism. In the invertebrates and in plants where such endocrine glands are unknown, it is probable that there are, nevertheless, regulating centers constituting various links in the developmental chain which starts with the fertilized egg and its chromosomes and ends with the fully formed parts and tissues. These endocrine glands and other developing controlling tissues are what the chromosomes make them.

This hypothesis receives support from the observations that have been made upon the physiology of the later stages of development, with their processes of folding of membranes, of concrescence, of disruption of parts by mechanical and histolytic processes, and the development of special tissues with their special kinds of form and substance such as are seen in the various connective tissues of the higher animals. These tissues are indeed responsive, in turn, not only to the hormones which seem so largely to control their development but also to external agents, such as pressure, gravity and radiant energy

The science of genetics has, in the past, suffered from too narrow a point of view. The evidence of the important rôle played by the chromosomes has been so overwhelming that it has blinded us to the presence of other agencies only indirectly ruled by the chromosomes. A consideration of all the facts should enforce the view that one of the greatest fields of biology, which has been comparatively untouched, is that of the physiology of development. Embryology has indeed been studied by the morphologist. A certain beginning has been made into the field of experimental embryology; but this has been confined largely to the early stages of development Something has been learned by transplantation experiments in later stages of the amphibia. But it remains true that the field of physiological embryology has been relatively little cultivated. The science of genetics can not be considered well established until we have some better conception of how the chromosomes do their work, of the chemical nature of the different developmental processes and the interaction of parts of the developing organism upon each other.

The appreciation of the complicated nature of development, the knowledge of the chain of developmental processes, each link of which is activated by a preceding link, helps us to understand more clearly the relation of heredity and environment. No physi-

ologist can fail to recognize that all development is under the control of agencies external to the developing center. In the earliest stages of development, indeed, the processes of differentiation seem to have a remarkable independence of environment. Even though the organism be turned inside out, as in the case of the lithium larvae of sea urchins produced by Herbst many years ago, still the spicules and other differentiating characters will be laid down in nearly normal fashion. But every student of plant genetics knows that the final form is dependent upon conditions of nutrition, temperature and the like, and students of human development are aware of the influence which the nervous system exerts upon the production of hormones. This nervous system is, of course, the organic complex which is most directly affected by external conditions and the production of hormones which has so marked an influence upon development. What is true in later stages is, no doubt, true in still earlier ones and thus one can see the basis for the conviction which has for a long time been held by thoughtful medical men that various kinds of shocks, or poisons introduced into the body, affect the development of the fetus. The striking cases of resemblance in close relatives and especially in identical twins occur where conditions of life are nearly uniform in the developmental period. Where these conditions affect differently the individuals with the same germ plasm the end result is a morphological difference. The student of genetics must take into account, therefore, chromosomes, hormones, other developmental impulses and environmental conditions if he would understand all the factors that determine development.

THE PHYSICAL BASIS OF DISEASE

X. UNSOLVED PROBLEMS IN RESEARCH MEDICINE

By THE RESEARCH WORKER
STANFORD UNIVERSITY

"COME down and spend your spring vacation in Pasadena," wrote the manufacturer. "You and the wife. Bring the kids. It will seem like old times to have children in the house once more."

"Yes, it's got me," said the manufacturer as he greeted his guests at the railway station, two weeks later. "Came to Southern California to scoff. Remain to worship. Have turned the Pittsburgh plant over to the boys. They're having the time of their lives. So'm I. Thus far it hasn't hurt profits. Now, if you young biologists will pile into the front seat. Or, am I mistaken in assuming you boys are going to be biologists when you grow up?"

"I'm goin' to be a surgeon-doctor," said the five-year-old, "not a guinea-pig doctor like Daddy."

"I go't'be a belly-doctor," said the three-year-old.

"We've not yet given up hope of making business men of both," said their mother.

2

That afternoon they drove by the new Astronomical Institute.

"That'll interest you," said the manufacturer. "Astronomical research. Has put Los Angeles on the high-brow map. Best publicity stunt in Southern California. Weighs the stars, Einstein theory and all that. Two million dollar endowment. Most expensive apparatus in the world. Single instruments costing \$40,000."

"Two million for astronomical research," said the research worker. "And not a dollar in Southern California for fundamental medical and hygienic problems. Don't expect me to be enthusiastic. Modern astronomy is an intellectual luxury that should be supported only after pressing problems of human life have been solved. In ten years' time this two million may lead to acceptance or rejection of the Einstein theory. Of remotest bearing on human life. The same sum spent in fundamental medical research might yield facts giving dominion over tuberculosis and cancer. As single biological facts have already given dominion over yellow fever and diphtheria.

"There is no city in the world where fundamental medical research is more needed than Los Angeles. A million people. Fully

a third belonging to politically active, anti-medical, anti-hygienic cults. African Voodooism masquerading in the nomenclature of Christianity. Financed by predatory commercial interests. A yearly sacrifice of ten thousand human lives. If you want a publicity stunt, do something to show there is at least a nucleus of hard-headed medical intelligence in this hag-ridden burg. Not a single new fundamental medical fact from all Southern California in the entire history of the state."

"But the doctors here have patients and guinea-pigs," said the manufacturer. "What more do they want?"

"Equipment. Leisure. Competent technicians. Stimulating leaders. Do you realize medical research requires a greater range of equipment than any other research field? Greater versatility. Electrical apparatus ten times as delicate as the radio. Microscopes rivaling in accuracy the telescopes of the astronomer. Micro-photography. Chemical equipment more varied than an industrial plant. Aseptic operating rooms. Facilities for hygienic care of experimental animals. Your $40,000 instrument turned into medical equipment would barely furnish a suite of rooms for one research worker."

"But the discoveries of the past were made with simple apparatus," insisted the manufacturer.

"The four-inch telescope of the ancient astronomer was the most up-to-date instrument of his time. His discoveries were made largely because he had this wonderful new instrument, beyond the reach of his contemporaries. A Newton to-day could add nothing to fundamental astronomical knowledge with such an instrument. The time is past when a novice, a clinical microscope and a handful of test-tubes can add fundamental facts to medical science.

"Besides there is the cost of animals. Technical assistants. Dogs, five dollars apiece. Scrupulous hygienic care for months. Monkeys, twenty dollars. In the research that gave the world its present partial control of infantile paralysis, one worker alone used a thousand monkeys. A problem that could not be studied on less expensive animals. Twenty thousand guinea-pigs in the fundamental researches that gave the present partial mastery of diphtheria. No provision in Southern California for serious research of this type."

3

That evening the retired superintendent and wife dropped in for a game of bridge.

"Secretary of our local anti-vivisection society," whispered the manufacturer, as they came up the walk. "Greetings, friends. May I introduce a professional vivisector."

"Just think," said the superintendent's wife to the wife of the research worker. "This morning, when I saw your husband on the lawn with the children and the dogs, I thought him such a kind, benevolent man. And he turns out so cruel, so immoral. Cuts up living animals."

"You object to vivisection on moral grounds?" asked the research worker.

"A sin equal to murder."

"I overheard your cook gossiping with the cook across the way. At your dinner last night you served capon and lamb fries. Four cockerels and two dozen lambs vivisected for your guests. Your dog has been spayed. We drove by the Glendale Farms. Cattle dehorned. Vivisection milk for your baby. The fur you wore as you entered is 'broadtail.' Unborn lamb. Often obtained by Caesarian section. Your objection to vivisection can not be on moral grounds. There must be some underlying psychological reason."

"It's an insult to God and man," said the superintendent, "to assume that soulless brutes are so nearly like man that advances in medicine can be made by cutting up animals. That's the psychological reason. An argument you can't answer."

"And medical progress?"

"By clinical observation, accumulated experience, experiments on human volunteers."

"I was a worker in Ehrlich's laboratory at the time he was developing salvarsan, the modern treatment of syphilis. Do you know the history of salvarsan?"

"Can't say I've been interested."

"Not interested! And ten per cent. of the people of California are syphilitic. Millions spent annually for the care of criminals, insane, demented. Mainly syphilitic. Fifty million dollars subtracted from the potential annual revenue of the state. If every fruit tree in California should die, the economic loss could be fully made up by the elimination of this one disease.

"Syphilis has been studied for four hundred years by clinical and statistical methods. Medieval religio-therapy, empirical formulae, health resorts. What result? One imperfect remedy, mercury. Requiring two years of daily dosing. A twenty-five per cent. probability of cure. No experimental method of study was possible. The germ of syphilis was not known. Apparently not transferable to lower animals.

"Twenty years ago the germ was discovered. Much to the surprise of clinicians it proved to be a very delicate protozoan-like parasite. More closely related to malarial fever and sleeping sick-

ness than to ordinary bacteria. Clinicians began to wonder if some of the newer therapeutic agents, successful with other protozoan diseases, might not be more valuable than mercury. No clinician, however, had the courage to substitute these agents for mercury with his patients. It would have meant the sacrifice of a hundred human lives to have adequately tested their possibilities.

"About fifteen years ago, it was found that a very mild disease could be produced in rabbits, by special inoculation methods with syphilitic virus That the protozoan-like germs remained alive in the rabbit's body long enough for therapeutic tests. For the first time lower animals could be substituted for human beings in therapeutic study of this disease. A wide range of new drugs was tried. An internal antiseptic found. Salvarsan. Tolerated by rabbits in sufficient doses to rid them of injected syphilis germs. Research workers were now for the first time in position to say to clinicians, 'Here is something of sufficient promise to warrant human experimentation.'

"Volunteers offered themselves to determine the safe dose for human beings. Salvarsan then substituted for mercury with hundreds of syphilitics. In sixty per cent., syphilis disappeared as by magic from their bodies. A sixty per cent. efficient drug. Replacing a twenty-five per cent efficiency of mercury. A few days' treatment, instead of the two years daily medication of the older clinicians. A result from animal experimentation carried over unchanged into human medicine."

"Salvarsan is immoral," said the superintendent's wife. "That disease was put on earth as a just punishment for sexual sin."

"An argument no biologist will attempt to answer. Biology thinks only of the thousand clean men with syphilitic wives. The ten thousand innocent women with syphilitic husbands. The hundred thousand blameless syphilitic babies. Ehrlich entered upon this research with religious fervor. 'Gain dominion over the biological world,' was the challenge he received from his conception of God Syphilis to him, a just punishment for biological ignorance."

"But Ehrlich was a Jew," interrupted the superintendent.

"Racial antipathy is no argument against the correctness of Ehrlich's point of view."

4

"Admitting, for the sake of argument, that vivisection was of use in developing salvarsan," said the superintendent, "and remember, I'm not really admitting it—that's no excuse for further syphilization of animals."

"How about the possibility of replacing the sixty per cent. efficiency of salvarsan with an eighty per cent. efficiency. Ninety per cent. A hundred per cent. Elimination of syphilis from the civilized world. That's the dream of current vivisectors. Sufficient progress has been made during the last few years to warrant the belief this dream will eventually come true. But only after thousands of animal experiments."

"But in most medical fields vivisection is useless," insisted the superintendent.

"Many human diseases have not yet been transferred or reproduced in lower animals. These diseases can only be studied by clinical methods. The greatest handicap to this clinical study is popular objection to autopsies. If you're seeking a way to assist clinicians with these diseases, nothing would be more valuable than popular education as to the value of autopsies."

"I'd never consent to the mutilation of a friend's body," said the superintendent's wife.

"The undertaker mutilates the body. Followed by internal chemical defilement."

"What a horrid evening!" said the superintendent's wife, as she and her husband returned to their home.

"Fanatical materialist!" said the superintendent.

5

Two evenings later the manufacturer and research worker were motoring through the down town sections of Los Angeles. Fragments of oratory reached them from groups collected at street corners:

"The octopus of Wall street," shouted one speaker. "A million tentacles. Reaching into every home. How long will ye remain dormant, ye sons of toil!" . . . "Monogamic marriage is contrary to nature," declared a second. "Marriage should be where love is. To-day I may love one. To-morrow I must be free to"—

"Strong meat for sixteen-year-olds," said the manufacturer.

"Come ye halt, ye blind," implored a third. "Bring thine broken bodies. Throw physics to the dog. Only in the blood of the" . . . "Then arose that great luminary of economics, Hen-ery George. 'The unearned increment is a public asset,' he said, 'not a private' " . . . "Absolutely without pain," a voice from an arcade. "I will now extract the tooth. I take this syringe. Painless Pinto's secret anesthetic" . . .

"What's his secret?" asked the manufacturer.

"The fact that he is using the same anesthetic as every other modern dentist."

"See them in their charnel house!" shrieked a woman. "Your child's collie writhing in their grasp! With fiendish grins they plunge the red-hot irons! And chuckle as he squirms."

"How are you going to answer such a charge?" asked the manufacturer.

"We tried to answer it in our laboratory a number of years ago, by admitting anti-vivisectionists freely to the operating rooms. A group of white-gowned medical students gaining skill as anesthetists and surgeons. A careful aseptic operation on a dog. A few words as to its research purpose. Complete reversal of attitude on the part of the anti-vivisectionist. Never knew it to fail. Even had anti-vivisectionists remain as voluntary anesthetists. Anti-vivisection propaganda has practically ceased in our community."

"Cruel and unnecessary!" continued the woman. "Even admitting their argument that in the past practical hunches have come from this devil's pastime—which is a lie!—a damnable lie!—nothing more can possibly come of it."

"How about it?" asked the manufacturer.

"For every fact thus far gained by animal experiment there are a hundred embarrassing problems to be solved only by vivisection.

"Enter any hospital. The first bed, inoperable cancer. The physician almost helpless before it. One tissue stimulated to excessive growth. Penetrating and destroying surrounding parts. He knows not the cause. No drug to stop it. One single new experimental fact may give him the desired cure. Inoperable cancer! If diagnosis could only have been made in the incipient stage. A single new experimental fact may give the necessary diagnostic test."

6

"But cancer's an extreme example," said the manufacturer.

"No. Fairly typical. Another example. Tuberculosis. No single disease in which more animal experiments have been done. Few diseases in which the physician to-day is so helpless. The causative agent is known. Method of transmission fairly well understood. Fairly reliable diagnostic test. But all attempts to find a method of rendering a normal individual sufficiently resistant to tuberculosis for safe daily contact with his fellow-man have failed. A new fundamental biological fact may give the much sought anti-tuberculosis vaccine. No reliable anti-serum has been found. No drug that will free the body from the invading germs. Nevertheless in time a salvarsan for tuberculosis is a certainty. A question of continued animal experimentation."

"Always thought tuberculosis well understood," said the manufacturer.

"Cancer and tuberculosis are typical of the present limits of medical knewledge. The neurologist. Almost helpless with neurasthenia. One single new chemical fact may give complete control. The obstetrician. Almost powerless with eclampsia. Years a clinical study. Ignorant of the fundamental cause. A new biological fact needed. The military surgeon. Ten soldiers dying from shock to one killed by bullets. Rudimentary ideas as to the biological factors involved.

"See the honor with which the profession has greeted insulin. A single vivisection product. The impatience with which it awaits similar products from other glands. See the pediatricians' intense interest in experimental studies of vitamins. The surgeons' eager hope from experimental cardiac surgery. Repair the heart valves. Already applied to man. The oculists' enthusiasm over successful eye transplantations in rats. The whole medical profession. Imploring experimental science for new fundamental biological facts."

7

"And the potential research workers of Los Angeles? For you have them here. Competent men. In spite of your seventy-five per cent. of quacks, incompetents and unscrupulous. These potential workers turning to the wealth of Southern California, 'Give us equipment, leisure, skilled technicians, that we may answer the Divine challenge, the Divine command.'

"And the wealth of Los Angeles? Continues with its motors and its golf. A few mumbling, 'Ah-e-gish! Ah-e-gish! Help us, lest we perish.' "

"I'll be damned if it does," said the manufacturer. "Say, do you know what this burg can do, when it gets up on its hind legs and begins to howl? Make any other city on the footstool look like thirty cents. Gad! I'll do it! I've been hungry for a job since I quit. Start it myself. Ten thousand. Two hundred men on the same basis. Two million in three months. No. We'll make it five million. Most up-to-date building in the world. Biggest research whale in all Europe as director. And that damned African legend over the front door."

"That's the research institute I had in mind when I improvised the legend," said the research worker.

THE MEDICAL OBSERVATIONS AND PRACTICE OF LEWIS AND CLARK

By Dr. J. HOWARD BEARD
UNIVERSITY OF ILLINOIS

On January 18, 1803, President Jefferson sent a private message to Congress requesting $2,500 for a "literary pursuit" which in reality was "for the purpose of extending the external commerce of the United States." By this method, Mr. Jefferson obtained the sanction of his government to explore the interior of the continent of North America, particularly the valleys of the Missouri and Columbia rivers and their tributaries, without arousing the suspicion of nations with possible claims upon the territory to be traversed.

Mr. Jefferson selected Meriwether Lewis, his private secretary, to lead the expedition. Lewis was a graduate of a Latin school, a keen observer, a captain of the regular army, and a soldier of experience. After his appointment Lewis went to Philadelphia, where he spent some time "under the tutorage of the distinguished professors of that place."

With the approval of the president, Lewis wrote to his friend, William Clark, inviting him to share in the fatigue, dangers and honors of the expedition on equal terms. Clark accepted with enthusiasm. William Clark was a veteran of Indian wars, an expert woodsman, a man of sterling integrity and of an indomitable spirit in the presence of hardship and danger. Although he possessed great native ability, his journals show his frontier life had been too strenuous to permit his becoming a scholar.

On February 28, 1803, President Jefferson sent confidential letters to Caspar Wistar and Benjamin Rush, informing them of his having received the approval of Congress to explore a transcontinental route to the Pacific Ocean, and of the selection and qualifications of Captain Lewis, the leader of the expedition. He requested them to prepare notes of those things which they thought worthy of observation and of inquiry by the leader of the party. He advised them that Captain Lewis would call upon them at Philadelphia within two or three weeks.

Besides the two leaders, the personnel of the expedition consisted of 43 men who were frontiersmen from Kentucky and soldiers from the western garrisons. York, a negro servant of Captain Clark, accompanied his master. Captain Lewis engaged as inter-

preter Charboneau, who brought with him his Indian wife, Sacajawea.

JEFFERSON'S INSTRUCTIONS TO LEWIS

While the principal objects of the expedition were commercial and political, Mr. Jefferson in his letter of instruction to Captain Lewis on June 20, 1803, specifically mentions a wide range of subjects worthy of special consideration and record as a means for enlarging the boundaries of knowledge. His directions pertaining to topics relating to medicine are peculiarly interesting and reflect the medical knowledge of his day.

> You will therefore endeavor to make yourself acquainted as far as diligent pursuit of your journey shall admit . . . with their (Indians) food, clothing & domestic accommodations; the diseases prevalent among them & the remedies they use; moral & physical circumstances which distinguish them from the tribes we know . . . carry with you some matter of the kine-pox; inform those of them with whom you may be of its efficacy as a preservative from the small-pox; and instruct & incourage them in the use of it. this may be especially done wherever you winter.

The fact that no physician accompanied the expedition and that both Captains Clark and Lewis practiced medicine rather systematically among the enlisted men and the Indian tribes with whom they came in contact make their journey of peculiar interest to the student of medicine. The dangers by land and by water and the length of time the members of the party were away from civilization excite his curiosity as to the methods and medicine used in the care and treatment of cases of accident and disease. The medical observations of both leaders are exceptional, but some of the "bedside notes" of Captain Lewis are so extraordinary as to do credit to a Dieulafoy or an Osler.

CLARK'S QUESTIONS FOR THE MAKING OF OBSERVATIONS

Having received the instructions of President Jefferson, Captain Clark transcribed them into a series of questions, the following part of which pertains to medicine and throws considerable light upon the subsequent observations of Clark and Lewis upon this subject:

PHYSICAL HISTORY AND MEDICINE

What is their State of Life as to longivity?
at what age do both Sexes usially marry?
How long do the Women usually succle their Children?
What is the diet of their Children after they wean them?
Is polygamy admited among them?
What is their most general diet, manner of cooking, time and manner of eating; and how doe they preserve their provisions?

What time do they generally consume in Sleep?
What are their acute diseases?
Is rheumatism, Pluricy, or bilious fevers known among them?
& does the latter ever terminate in a vomiting of black matter?
What are their chronic diseases—are palsy, apoplexy, Epilepsy, Madness, the goiture (or Swelled Neck) and the Venereal disease known among them?
What is the mode of treating the Small pox particularly?
Have they any other disease amongst them, and what are they?
What are their remidies for their different diseases?
Are artificial discharges of blood used among them?
In what manner do they generally induce evacuation?
Do they ever use Voluntary fasting?
What is the nature of their baths, and at what time of the day do they generally use them?
at what age do their women begin and cease to menstruate?

In dealing with longevity, the age of adolescence, the character of the pulse influenced by age, sex and the time of the day, the diet of the Indians and their method of preparing it and the number of hours given to sleep, Clark's questions reveal to a considerable degree the advancement of physiology at the beginning of the nineteenth century. The nature of the baths and the time of the day at which they were taken further emphasize the interest in this subject and in hygiene.

Rheumatism receives special consideration because of its wide prevalence. Exposures, climatic changes and hardships made rheumatism a very common ailment among pioneers. Pleurisy, so-called, was well known to the public, because the same conditions were conducive to disease of the lungs and because tuberculosis was common.

Bilious fevers in 1803 were a generic term including typhoid fever, typhus fever, malaria, yellow fever, food poisoning and other illnesses with intestinal symptoms accompanied by a rise in temperature Fevers were common and thought to be due to the exhalations of marshes, of decayed vegetable matter, to rottening timber, stagnant water, lack of drainage or bad sewerage.

Bilious fever terminating in a "vomiting of black matter" was yellow fever. This disease was attracting considerable attention, as it had killed over 4,000 people in Philadelphia in 1793. New York and Philadelphia suffered epidemics in 1798 and New York again in 1803, the year the Lewis and Clark Expedition started up the Mississippi.

Jefferson's instructions to Lewis and Clark to note the Indians' treatment of smallpox, to carry with them vaccine virus and to inform the Indians of its use shows his interest and efforts to make use of the epoch discovery of Jenner. In 1800 Jenner had sent cowpox virus to Dr. Benjamin Waterhouse of Boston. Waterhouse

sent the virus to the president, who had some 300 people vaccinated in Washington.

Unfortunately the virus given to Lewis seems to have lost its potency. In his letter to Jefferson on October 3, 1803, from Cincinnati, Lewis wrote: "I would thank you to forward me some of the Vaxcine matter, as I have a reason to believe from experiments with what I have, that it has lost it's virtue." There is no further record of Jefferson sending a second supply of virus or of it being used by either Lewis or Clark.

Venereal disease among the aborigines of America had been known since the return of Columbus to Barcelona in 1493. Its extent, incidence and origin were subjects of continued speculation and study by scientists of the eighteenth and nineteenth centuries. The prevalence of a disease of so great social significance would naturally stimulate inquiry in such scientific minds as those of Jefferson, Wistar and Rush.

Practically nothing was known of the actual cause of goiter one hundred years ago. Its exophthalmic form attracted attention wherever present and created much interest as to its nature. "Swelled neck" or simply goiter was common among the Indians and settlers in the Great Lakes Region, which fact in all probability accounts for Clark's question concerning it.

Apoplexy, epilepsy, palsy and madness are specifically mentioned in Clark's list of questions, because little was known concerning their pathology and their symptoms were so characteristic and awe-inspiring as to excite fear and horror. Rabies was common among domestic animals and not very infrequent among the early pioneers. It caused so much destruction among wolves that many observers believed it did more to exterminate them than the guns of our forefathers or the advancement of civilization.

The Medicine Chest

Lewis and Clark started on their trip during the drastic era of medicine. They lived during the period when the great attack upon disease was directed through the emunctories. In their day, the most powerful weapons in the armamentarium of the physician were the lancet and the eliminant. Purgation, sweating, salivation, blistering and bleeding were the shock troops hurled against entrenched disease. They frequently cured but never failed to impress the patient.

The following bill, made by Purveyor Israel Wheelen "for the use of M. Lewis Esquire on his tour up the Mississippi and supplied by his order," gives a clear conception of the therapeutics of the time and is also suggestive of the medical emergencies anticipated by the leaders of the expedition.

Bill of Gillapsy & Strong for Medicine

Israel Wheelen Purveyor Bought of Gillapsy & Strong the following articles for the use of M. Lewis Esquire on his tour up the Missisipi River, and supplied by his Order:—Viz

15	℔. Pulv. Cort. Peru	$30.00
½	℔. " Jalap	.67
½	℔. " Rhei (Rhubarb)	1.00
4	oz. " Ipecacuan	1.25
2	℔. " Crem. Tart.	.67
2	oz Gum Camphor	.40
1	℔. " Assafoetid	1.00
½	lb. " Opii Turk. opt	2.50
¼	℔. " Tragacanth	.37
6	℔. Sal Glauber 10	.60
2	℔. " Nitri 33½	.67
2	℔. Copperas	.10
6	oz. Sacchar. Saturn. opt.	.37
4	oz. Calomel	.75
1	oz. Tartar Emetic	.10
4	oz. Vitriol Alb.	.12
½	℔. Columbo Rad.	1.00
¼	℔. Elix. Vitriol	.25
¼	℔. Ess. Menth. pip.	.50
¼	℔. Bals. Copaiboe	.37
¼	℔. " Traumat.	.50
2	oz. Magnesia	.20
¼	℔. Indian Ink	1.50
2	oz. Gum Elastic	.37
2	oz. Nutmegs	.75
2	oz. Cloves	.31
4	oz. Cinnamon	.20
		$46.52

4	oz. Laudanum	.50
2	℔. Ung. Basilic Flav., 50	1.00
1	℔. " e lap Calimin .50	.50
1	℔. " Epispastric	1.00
1	℔. " Mercuriale	1.25
1.	Emplast. Diach. S.	.50
1.	Set Pocket Insts. small	9.50
1.	Teeth " "	2.25
1.	Clyster Syringe	2.75
4.	Penis do.	1.00
3.	Best Lancets .80	2.40
1.	Tourniquet	3.50
2	oz. Patent Lint	.25
50	doz. Bilious Pills to Order of B. Rush 10	5.00
6	Tin Canisters 25	1.50
3	8 oz. Gd. Stopd. bottles	1.20
5	4 oz. Tinctures do	1.85
6	4 oz. Salt Mo.	2.22
1	Walnut Chest	4.50
1	Pine do.	1.20
	Porterage	.30
		$90.69

The above bill shows the medicine chest contained among other things fifteen pounds of febrifuge, approximately 1,500 doses of purgative, 1,100 of emetic and 3,500 of diaphoretic. Blistering was provided for by one pound of epispastric or cantharidis ointment; salivation by four ounces of calomel and one pound of mercury ointment. Three of the best lancets were included for bleeding. In addition to the drugs provided by the purveyor other records reveal that in the medicine chest there were one pound of the flour of sulphur, eight ounces of borax, two sticks of simple diachylon and three extra lancets. Some of the men also carried their favorite medicines. Captain Lewis seems to have had a generous supply of Scott's Pills.

THERAPEUTICS

Both Captains Lewis and Clark showed great resourcefulness in bringing relief to the men under their command when sick. They

drew upon the medical supplies when needed, but if those were not available or the medicines did not seem to produce the desired result, they did not hesitate to make use of the plants along the route or to accept the suggestions of the other members of their party.

Gastro-enteritis

Gastritis and enteritis were very common among the party, due to the diet, exposure and fatigue. Meat composed the greater part of their food and was often neither properly preserved nor sufficiently fresh for use. Polluted water, water impregnated with salts of a laxative action and roots eaten containing a purgative principle produced disorders of the stomach and intestines. Fatigue before and after meals and the method of preparing such foods as could be obtained contributed to the discomfort of the party.

The usual treatment of gastritis was a dose of Glauber salts. In the more severe cases 35 drops of laudanum was administered after the saline. When Lewis became suddenly ill while out of the reach of his medicine chest he was not averse to try an experiment with "some simples" that "first struck his attention."

> I was taken with such violent pain in my intestines that I was unable to partake of the feast of marrow bones. my pain still increased and towards evening was attended with a high fever; finding myself unable to march, I determined to prepare a camp of some willow boughs and remain all night. Having brought no medicine with me, I resolved to try an experiment with some simples; and the Choke cherry which grew abundantly in the bottom first struck my attention; I directed a parcel of small twigs to be geathered, striped of their leaves, cut into pieces of about two inches in length and boiled in water until a strong black decoction of an astringent bitter taste was produced; at sunset I took a point (pint) of this decoction and about an hour after repeated the doze, by ten in the evening I was entirely relieved from pain and in fact of every symptom of the disorder forsook me; my fever abated, a gentle perspiration was produced and I had a comfortable and refreshing nights rest. This morning I felt myself quite revived, took another portion of my decoction and set out at sunrise.

Emesis was also employed in certain cases of gastric disorder, but the "doctors" were not always in entire agreement as to the best emetic to use. Their difference of opinion had little effect upon the prompt recovery of the negro York, who had food poisoning. Clark observes, "my man York sick; I give him a dost of Tartar." Lewis states, "Capt. Clarks black man York is very unwell today and he gave him a doze of tartar emetic which operated very well and he was much better in the evening. this is a description of medicine that I never have recourse to in my practice except in cases of intermittent fever."

Lewis was no less successful than Clark in obtaining prompt relief for his sick associates.

I found Wiser very ill with a fit of the cholic. I sent Sergt. Ordway who had remained with him for some water and gave him a dose of the essence of Peppermint and laudinum which in the course of half an hour so far recovered him that he was enabled to ride my horse.

Clark was in no sense a drug nihilist. In treatment he was energetic, thorough and drastic when his patients did not show prompt improvement. "Capt. Lewis still very unwell, Several men taken sick on the way down, I administered Salts Pils Galip (jalap) Tartar emetic etc. I feel unwell this evening."

VENESECTION

Blood-letting was almost considered a panacea during the first quarter of the 19th century. It was highly recommended by the great majority of physicians and many laymen were loud in its praise. Before the patient was bled he was given an emetic, purged, salivated with mercury and often blistered and sweated. The purpose of this drastic elimination was to abstract excitement, congestion and inflammation from the vital organs. Theoretically, such complete depletion left nothing upon which the disease could work. Therefore, the patient had an opportunity to recover.

With Captain Clark venesection was a sovereign remedy.

one man was taken violently Bad with the plurisie, Bleed & apply those remedies Common to that disorder. I bled the man with the plurisy today (next day) & swet him. The sick man yesterday is getting well. Drewyer was taken last night with a violent pain in his side. I bled him. This evening (next day) Drewyer went in quest of his traps and took an otter. Schcagagwea, our Indian woman verry sick. I blead her.

Lewis was more conservative in the practice of blood-letting but no less versatile and prompt in using it, once he had decided it was desirable.

Whitehouse one of them (the party) much heated and fatigued on his arrival drank a very hearty draught of water and was almost taken instantly extremely ill. his pulse were full and I therefore bled him plentifully from which he felt great relief. I had no other instrument with which to perform this operation, but my pen knife, however it answered very well.

RHEUMATISM

Coldness, dampness and hardship caused much muscle soreness, sprains, strains and arthritis among the members of the party. Sergeant Gass gives a clear account of the conditions experienced by the men that were conducive to this affection.

Some of the men are complaining of rheumatic pains, which are to be expected from the wet and cold we suffered last winter; during which, from the 4th of November 1805, to the 25th of March 1806, there were not more than twelve days in which it did not rain and of these but six were clear.

Captain Clark describes attacks of the disease among his men, in an Indian girl, and in himself. His skill in the treatment of rheumatism was of such high order as to be worthy of a fee of the best trained specialists. "We received a second horse for medicine and prescription to a little girl with the rheumatism whome I bathed in worm water, and anointed her a little with balsam capivia."

Captain Lewis, by using hot applications in treating "rheumatism," anticipated modern methods.

> Last night at 1 oClock I was violently and Suddenly attacked with the Rheumatism in the neck which was so violent I could not move. Capt. Lewis applied a hot Stone Raped in flannel, which gave me some temporary ease. . . . A cloudy morning (next day) Some Snow. Set out early. . . . R. Fields with the Rhumitism in his neck, P Crussat with the Same complaint in his Legs,—the party otherwise well, as to myself I feel but slight Simptoms of that disordr at this time (three days later). . . . John Shields sick today with the rheumatism.

Colds and Influenza

The exposure of the men to wet and to chill produced an epidemic of common colds. In February, 1806, Clark described a disease with which his men were affected that would seem to warrant the conclusion that the influenza which had been epidemic in eastern parts of the United States had succeeded in locating his expedition. Many of the men were ill. "The general complaint appears to be bad colds and fevers, with a violent pain in the head and back, something I believe of the influenza."

The malady attacked the men suddenly, caused great prostration, but was quickly followed by improvement, except in the cases of Willard and Bratton. Private Bratton evidently suffered a complication and ill for a long time until given rather strenuous sweat baths. Convalescence was slow, due largely to inadequate diet. The failure to gain strength may have also been caused, in a measure, by prostration. "The diet of the sick is so inferior that they recover their strength but slowly. none of them are now sick but all in a state of convalescence, with keen appetites and nothing to eat except lean Elk meat."

On February 16, Lewis notes that:

> Bratton is still very weak and complains of a pain in the lower part of the back when he moves which I suppose proceeds from dability. I gave him barks. Gibson's fever still continues obstenate tho not very high; I gave him a dose of Dr. Rush's which in many instances I have found extreemly efficacious in fevers which are in any measure caused by the presence of boil. the nitre has produced a profuse perspiration this evening and the pills operated late at night his fever after which abated almost entirely and he had a good night's rest.

Continue the barks with Bratton, and commenced them with Gibson his fever being sufficiently low this morning to permit the uce of them. I therefore think that there is no further danger of his recovery.

Gave Willard and bratton each a doze of Scotts pills; on the former they operated and on the latter they did not Gibson still continues the barks three times a day and is on the recovery. fast.

Bratton is much worse today, he complains of a violent pain in the small of his back and is unable in consequence to set up. we gave him one of our flanel shirts, applied a bandage of flannel to the part and bathed and rubed it well with some vollatile linniment which I prepared with sperits of wine, camphor, castile soap, and a little laudanum. he felt better in the evening.

Two weeks later the men were still sick and Bratton and Willard are causing Clark uneasiness.

Maney of our men are still complaining of being unwell; Bratton and Willard remain weak principally I believe for the want of proper food. I expect when we get under way that we shall be much more healthy. it has always had that effect on us heretofore.

Our sick men Willard and Bratton do not seem to recover; the former was taken with a violent pain in his leg and thye last night. Bratton is now so much reduced that I am somewhat uneasy with respect to his recovery; the pain of which he complains most seems to be settled in the small of his back and remains obstinate. I believe it is the rheumatism with which they are both affected.

A Russian Bath in the Wilderness

Three months after the beginning of his attack Bratton's ailment had resisted every remedy that Clark and Lewis could devise. John Shields, the gunsmith of the expedition, recommended sweating with the most happy results.

William Bratton still continues very unwell; he eats heartily digests his food (very) well, and has recovered his flesh almost perfectly yet is so weak in the loins that he is scarcely able to walk, nor can he set upright but with the greatest pain. We have tried every remidy which our ingenuity could devise, or with which our stock of medicines furnished us, without effect. John Shields observed that he had seen men in similar situation restored by violent sweats. Bratton requested that he might be sweated in the manner proposed by Shields to which we consented. Shields sunk a circular hole of 3 feet diameter and four feet deep in the earth. he kindled a large fire in the hole and heated well, after which the fire was taken out a seat placed in the center of the hole for the patient with a board at bottom for his feet to rest on; some hoops of willow poles were bent in an arch crossing each other over the hole, on these several blankets were thrown forming a secure and thick orning of about 3 feet high. the patient being striped naked was seated under this orning in the hole and the blankets well secured on every side. the patient was furnished with a vessell of water which he sprinkled on the bottom and sides of the hole and by that means creates as much steam or vapor as he could possibly bear, in this situation he was kept about 20 minutes after which he was taken out and suddenly plunged into cold water twise and was then immediately returned to the sweat hole where he was continued three quarters

of an hour longer then taken out covered up in several blankets and suffered to cool gradually. during the time of his being in the sweat hole, he drank copious draughts of a strong tea of horse mint. Sheilds says that he had previously seen the tea of Sinneca snake root (The Seneca snake-root) used in the stead of the mint which was now employed for the want of the other which is not to be found in this country. the experiment was made yesterday; Bratton feels himself very much better and is walking about today and says he is nearly free from pain.

A week after having his semi-Russian bath, Bratton "has so far recovered that we can well consider him an invalid no longer. he has had a tedious illness which he boar with much fortitude and firmness." He apparently endured his treatment with equal resignation.

The Tragic Story of Smallpox

A stellar rôle in the great tragedy of the disappearance of the American Indian was played by variola. It was more deadly to the natives than the bullets of the paleface, more unrelenting than his insatiable desire for land. It destroyed whole villages, drove remnants of tribes to desperation, and so weakened many Indian nations that they were easily conquered by their enemies. The following extracts from Clark's Journal cover a three-year period of travel and therefore show that smallpox had swept through the Indian villages from the mouth of the Missouri River, over the Great Divide, and down the valley of the Columbia to the Pacific Ocean.

The men sent to the Mahar Town last evening . . . returned and informed us that they Could not find the Indians, nor any fresh Sign those people have not returned from their Buffalow hunt. Those people haveing no houses no Corn or anything more than the graves of their ancestors to attach them to the old Village, Continue in purseute of the Buffalow longer than others who has greater attachments to their native village. The ravages of the Small Pox which Swept off (about 4 years ago) 400 men and Womin and children in perpopotion has reduced this nation not exceeding 300 men and left to the insults of their weaker neighbors, which before was glad to be on friendly turms with them.

I am told when this fatal malady was among them they Carried their franzey to verry extraordinary length, not only of burning their Village but they put their wives and children to Death with a view of their going together to some better Countrey. . . . The cause or way those people took the Small Pox is uncertain, the most Probable, from Some other nation by means of a war party.

This nation (Clotsop) is the remains of a large nation destroyed by the Smallpox or Some other disease which those people were not acquainted with, they Speak the same language of the Chinnooks and resemble them in every respect except that of stealing, which we have not cought them at as yet.

I have endeavored to obtain from those people the situation of their nation, (Shah-ha-la), if scattered or what had become of the natives who must

have peopled this great town. an old man who appeared of some note among them and father to my guide brought forward a woman who was badly marked with Small pox and made signs that they all died with the disorder which marked her face, and which she was very near dieing with when a girl. from the age of this woman this Distructive disorder I judge must have been 28 or 30 years past, and about the time the Clatsops inform us that this disorder raged in their towns and distroyed their nation.

Lewis's single comment on the subject of smallpox is in confirmation of those of Clark as to the devastation of variola among the Clatsops, who lived near the mouth of the Columbia River, where the expedition wintered in 1805–1806.

The small pox has destroyed a great number of the natives in this quarter. it prevailed about 4 years since among the Clatsops and destroyed several hundred of them, four of their chiefs fell victyms to its ravages. those Clatsops are deposited in their canoes on the bay a few miles below us. I think the late ravages of the smallpox may well account for the number of remains of vilages which we find deserted on the river and Sea coast in this quarter.

Social Disease

Lewis repeatedly observed the presence of venereal disease and its terrible complications among the Indians. Their method of treatment in general was ineffective, and the scourge once acquired raged almost without control. Some of the enlisted men of the party of the expedition became infected and gave Lewis an opportunity to exhibit his skill as a syphilologist. As mercury was the chief specific of the day and extolled by Dr. Rush as the "Samson of the Materia Medica," Lewis gave this drug every opportunity to destroy this Philistine of the race. "I cured him as I did G. . . . last winter by the use of murcury."

I was anxious to learn whether these people (Shoshone Indians) had the venerial, and made the inquiry through the interpreter and his wife; the information was that they sometime had it but I could not learn their remedy; they most usually die with its effects. this reason is strong proof that these disorders (Neisser infection and Lues) are native disorders of America. tho' these people have suffered much by the small pox which is known to be imported and perhaps those other disorders might have been contracted from other Indian tribes who by a round of communications might have obtained from the Europeans since it was introduced into that quarter of the globe. but so much detached on the other hand from all communication with the whites that I think it most probable that those disorders are original with them.

I cannot learn that the Indians have any simples which are sovereign specifics in the cure of this disease; and indeed I doubt very much whether any of them have any means of effecting a perfect cure. When once this disorder is contracted by them it continues with them during life; but always ends in decrepitude, death, of premature old age; tho' from the use of certain simples together with their diet, they support this disorder with but little inconvenience for many years, and even enjoy a tolerable share of health.

Obstetrics and Gynecology

It was vital to the success of the expedition that horses should be provided by the Snake Indians for the party to make portage from the Missouri to the Columbia River. To insure a friendly negotiation with the Snakes, Lewis took with him Sacajawea, a Shoshone captive, the purchased wife of Charboneau, his interpreter. She was the only woman permitted to accompany the expedition, and it was her presence that caused Lewis to record his observation upon the pharmacological effect of the rattle of the rattle snake in parturition.

About five Oclock this evening Sacajawea was delivered of a fine boy. This was the first child which this woman had boarn, and as is common in such cases her labor was tedious. Mr. Jessome informed me that he had freequently administered a small portion of the rattle of the rattle snake, which he assured me had never failed to produce the desired effect, that of hastening the birth of the child; having the rattle of a snake by me I gave it to him and he administered two rings of it to the woman broken in small pieces and added to a small quantity of water. She had not taken it more than ten minutes before she brought forth, perhaps this remedy may be worthy of future experiments, but I must confess that I want faith as to its efficacy.

Lewis gives the following comment on the ease of parturition among the native women.

It appears to me that the facility and ease with which the women of the aborigines of North America bring fourth their children is reather a gift of nature than depending as some have supposed on the habitude of carrying heavy burthens on their backs while in the state of pregnacy. if a pure and dry air, an elivated and cold country is unfavorable to childbirth, we might expect every difficult incident to that operation of nature in this part of the continent; again as the Snake Indians possess an abundance of horses, their women are seldom compelled like those in other parts of the continent to carry burthens on their backs, yet they have their children with equal convenience, and it is a rare occurrence for any of them to experience difficulty in childbirth. I have been several times informed by those who were conversent with the fact, that the Indian women who are pregnant by white men experience more difficulty in childbirth than when pregnant by an Indian. if this is true it would go far in support of the opinion I have advanced.

Both Clark and Lewis recorded the custom among the Indians of periodic isolation of their women somewhat similar to the practice of Biblical times. In this regard Clark records:

This man has a daughter who is not permitted to acoiate with the family but sleeps at a distance from her father's camp, and when traveling follows at some distance behind. in this state I am informed that the female is not permited to eat, nor to touch any article of culinary nature or many occupation. . . .

At all these lodges of the Chopunnish I observe and appendage of a small lodg with one fire which seems to be the retreat of their women, the men

are not permitted to approach this lodge within a certain distance and if they have anything to convey to the occupants of this little hospital they stand at a distance of 50 or 60 paces and throw it towards them as far as they can and retire. (Lewis)

The Forest Clinic

Clark and Lewis practiced medicine among the Indians, Clark actually holding clinics, and treating as many as forty patients within a few hours. He became the favorite physician and enjoyed an enviable reputation among them. Both he and Lewis seemed to have been endowed with that broad human sympathy, keen sense of responsibility, understanding and integrity that are the best traditions of the true followers of Hippocrates.

Captain Clark appreciated the value of the mental element in successful treatment. He used the methods and the medicine likely to produce a favorable impression upon the minds of his patients. Accordingly, his prestige as a physician steadily increased among the Indians.

> Capt. C. (with much ceremony washed & rubed) gave an indian man some volatile liniment to rub his knee and thye for a pain of which he complained. the fellow soon after recovered and has never ceased to extol the virtues of our medicines and the skill of my friend Capt. Clark who is their favorite phisician and has already received many applications.

Clark informs us that

> After brekfast I began to administer eye water and in a fiew minuts had near 40 applicants with sore eyes, and many others with other complaints most common Rhumatic disorders and weaknesses in the back and loins perticularly the womin. some simple cooling medicenes to the disabled Chief, to several women with rhumatic effections & a man who had a swelled hip &c. . . .
>
> Thompson, one of the enlisted men, returned from the village accompanyed by a train of invalides consisting of 4 men 8 women and a child. eye water was administered to all; to two of the women cathartics were given, to a third who appeared much dejected and who from their account of her disease we supposed it to be histerical, we gave thirty drops of laudanum. the several parts of the others where the rheumatic pains were seated were well rubed with a volitile linniment. All of these poor wretches thought themselves much benefited, and all returned to their village well satisfyed. . . .
>
> All tribes which I have passed on these waters (Columbia River) who live on fish maney of different sectes who have lost their teeth about middle age. Some have their teeth worn to the gums, perticelarly those of the upper jaw, and the tribes generally have bad teeth, the cause of it I can not account for, sand attached to the roots & the method they have of useing the dried Salmon is mearly worming it and eating the rine & scales with the flesh of the fish, no doubt contributes to it.

Lewis gives a striking description of two of their clinics that they held in the spring of 1806:

They (the Wallahwallah Indians) brought several diseased persons to us for whom they requested some medical aid. one had his knee contracted by the rheumatism, another with a broken arm &c. to all of which we administered. Ulsers and irruptions of the skin on various parts of the body are also common diseases among them. . . .

Many of the natives apply to us for medical aid which we gave them cheerfully so far as our skill and store of medicine would enable us. schrofela, ulsers, rheumatism, soar eyes and the lost of the uce of their limbs are the most common cases among them. the latter case is not very common but we have seen three instances of it among the Chopunnish.

Lewis the Clinician

Sacajawea became very ill on June 10, 1805, while Lewis was away from camp with a small party making observations. On the appearance of her symptoms Clark bled her, and again on the following day. On the fourth day of her illness he administered salts and applied poultices of Peruvian bark and laudanum. She grew steadily worse, refused medicine and her condition became so alarming that her husband requested Captain Clark to have the party turn back with her. At the height of her illness Captain Lewis arrived at camp on June 16 and made the following notes of her condition:

About 2 p. m. I reached the camp, found the Indian woman extreemly ill and much reduced by her indisposition. . . . two dozes of barks and opium which I had given her since my arrival had produced an alteration in her pulse for the better; they were now much fuller and more regular. I caused her to drink the mineral water altogether (from sulphur springs). when I first came down her pulse were scarcely perceptible, very quick, frequently irregular, and attended with strong nervous symptoms, that of twitching of the fingers and leaders of the arm; now the pulse had become regular much fuller and a gentle perspiration had taken place; the nervous symptoms have also in a great measure abated, and she feels herself much freer from pain. she complains principally of the lower region of the abdomen, I therefore continued the cataplasms of barks and laudanum which had been previously used by my friend Capt. Clark. . . .

The Indian woman much better today (June 17); I have still continued the same course of medicine; she is free from pain clear of fever, her pulse regular, and eats heartily as I am willing to permit her of broiled buffaloe well seasoned with pepper and salt and rich soope of the same meat; I think therefore that there is every rational hope of her recovery. . . .

·The Indian woman is recovering fast, she set up the greater part of the day (June 18), and walked out for the first time since she arrived here; she eats heartily and is free from fever or pain. I continue same course of medicine and regimen except that I added one doze of 15 drops of the oil of vitriol today about noon. . . .

American medicine lost a great leader when Meriwether Lewis responded to the urge of adventure instead of to the wooings of Panaciea, the daughter of Aesculapius. His natural gifts, if

trained, would have undoubtedly qualified him as a most worthy successor of Benjamin Rush. His rare powers of observation, his wide information and his capacity to recognize and to differentiate the various symptoms of disease would have made him one of the great clinicians of his day.

A Chief of considerable note at this place has been for three years incapable of moving a single limb but lies like a corps in whatever position he is placed, yet he eats heartily, digests his food perfectly, in short were it not that he appears a little pale from having lain so long in the shade he might well be taken for a man in good health. As he complains of no pain in any particular part we conceive it can not be the rheumatism, nor do we suppose that it can be a parelitic attack or his limbs would have been more deminished. we have supposed that it was some disorder which owed its origine to a diet of particular roots, perhaps, and such as we have never before witnessed. . . .

While at the village of the "broken arm" we had recommended a diet of fish or flesh for this man and a cold bath every morning. we had also given him a few doses of creem of tartar and flour of sulphur to be repeated every third day. this poor wretch thinks that he feels himself somewhat better but to me their appears no visible alteration. we gave him a few drops of Laudanum, and a little portable soup. . . .

We caused a sweat to be prepared for the chief in the same manner in which Bratton had been sweated, this we attempted but were unable to succeed, as he was unable to set up or be supported in the place. we informed the indians that we knew of no relief for him except sweating him in their sweat houses and giving him plenty of the tea of the horse mint which we shewed them. and that this probably would not succeed as he had been so long in his present situation. I am confident that this would be an excellent subject for electricity and much regret that I have not in my power to supply it. . . .

the indians were so anxious that the sick Cheif be sweated under our inspection that they requested we would make a second attempt today, (May 27, 1806), accordingly the hole was somewhat enlarged and his father went in the hole with him and sustained him in a proper position during the operation; we could not make him sweat as copiously as we wished. after the operation he complained of considerable pain, we gave him 30 drops of laudanum which soon composed him and he rested very well. . . .

The sick Cheif is much better this morning (May 28, 1806) he can use his hands and arms and seems much pleased with the prospect of recovering, he says he feels much better that he has for a great many months. the Chief has much more use of his hands and arms. he washed his hands and arms. he washed his face himself today (May 29, 1806) which he has been unable to do previously for more than twelve months.

We gave the Chief a severe sweat today (May 30, 1806), shortly after which he could move one of his legs and thys and work his toes pretty well, the other leg he can move a little; his fingers and arms seem almost entirely restored. he seems highly delighted with his recovery.

We gave the Indian Cheif another sweat today (June 5, 1806), continuing it as long as he could bear it, in the evening he was very languid but still continued to improve in the use of his limbs. The sick Cheif is fast on the recovery (Jun. 8, 1806), he can bear his weight on his legs, and has acquired a considerable portion of strength.

The acute illness of the interpreter's child offered Lewis the opportunity to explore the field of pediatrics. He entered it with the same confidence that had taken him over the Continental Divide and had found favor for him in negotiation with the Indians. He exhibited the skill and resourcefulness that was ever his custom, and to which failure was foreign. His keenness of observation, attention to details, and ability to make the most of the medical supplies available, sustained nature until recovery was assured.

> Charbono's Child is very ill this evening; he is cuting teeth, and for several days past has had a violent lax which having suddenly stoped he was attacked with a high fever and his neck and throat are much swollen this evening. We gave him a doze of cream of tartar and flour of sulphur and applyed a poultice of boiled onions to his neck as warm as he could bear it. . . .
> The cream of tartar and sulpher operated several times on the child in the course of the last night, he is considerably better this morning, tho' the swelling of the neck has abated but little; we still apply poltices of onions which we renew frequently in the course of the day and night. The child was very restless last night, (twenty-four hours later), its jaw and the back of its neck are much more swollen than they were yesterday tho' his fever had abated considerably. we gave it a dose of creem of tartar and employed a fresh poultice of onions. . . .
> The Child is more unwell than yesterday (third day of illness). we gave it a doze of creem of tartar which did not operate, we therefore gave it a clyster in the evening. The clyster given the child last evening operated very well. It is clear of fever and much better this evening, the swelling is considerably abated this evening and it appears as if it would pass off without coming to a head. we still continue fresh poltices of onions to the swolen part. . . .
> Charbono's son is much better today (fifth day of illness), tho' the swelling on the side of the neck I believe will terminate in an ugly imposthume a little below the ear. The child is also better (sixth day of illness), he is free of fever the imposthume is not so large but seems to be advancing to maturity. The child is also on the recovery (one week after onset of disease). . . .

Clark, the Surgeon

Lewis practiced surgery only in emergencies; it was Clark's specialty. He had to care for infections, dislocations, fractures, gunshot wounds and many other painful injuries suffered by the men under his command. The members of the party acquired numerous abscesses and boils which were due to slight abrasions of the skin to which they were always exposed, and to insect bites. When the men visited Indian lodges they often came away infested with fleas. Mosquitoes were so numerous as to provide both a means for infection and an explanation for Captain Clark's rare poor marksmanship. "The Musquetors were so numerous that I could not keep them off my gun long enough to take sight and by that means Missed." Lewis ascribed the boils to the muddiness

of the river water, but noted that the general health of the party was excellent. His treatment of them consisted of poultices of Indian meal or elm bark. In rare instances, he employed the lance.

Bruises, cuts and lacerations were numerous among men subjected to such hardships.

Hall had his foot and ankle much injured yesterday by the fall of a large stick of timber; the bones were fortunately not broken and I expect he will again be able to walk shortly. Most of the party complain of their feet and legs being very sore. it is no doubt caused by walking over rough stone and deep sand after being accustomed to a soft soil. My legs and feet give me much pain. I bathed them in cold water from which I experienced considerable relief. . . .

Potts cut one of the large veins on the inner side of the leg with one of the large knives; I found much difficulty in stoping the blood which I could not effect untill I applyed a tight bandage with a little cushon of wood and tow on the vein below the wound. [Four days later] Pott's legg is inflamed and very painfull to him. We apply a poltice of the roots of Cows, [Lomatium]. . . .

Pott's legg which has been much swolen and inflamed for several days is much better this evening and gives him but little pain. we applyed the pounded roots and leaves of the wild ginger (Asarum caudatum) from which he found great relief. . . . Willard had cut his knee very badly with his tommahawk. . . . Wiser had cut his leg, badly with a knife and was unable in consequence to work. Shannon cut his foot with the ads in working at the perogue. . . .

Gibson in attempting to mount his horse after shooting a deer this evening fell on a Snag and sent it nearly two inches into the Muskeler part of his thy. he informs me this snag was about 1 inch in diameter burnt at the end. this is a very bad wound and pains him exceedingly. I dressed the wound. he slept but very little last night and complains of great pain in his Knee and hip as well as his thy. . . . halted to let Gibson rest. his leg become So numed from remaining in one position, as to render it So Painful that he could not set on the horse after rideing about 2 hours and a half.

Two days later Gibson's wound is beginning to heal and Clark is hopeful "that it will get well in time for him to accompany Sergeant Pryor with the horses to the Mandans."

Clark had his surgical skill put to the test when Sergeant Pryor put his shoulder out of place. He made four attempts before he could replace it. (About a year later the shoulder was dislocated again while the sergeant was carrying meat.) Gibson also suffered a subluxation of his shoulder but the dislocation was promptly reduced.

The most dangerous injury received by any member of the expedition was when (August 10, 1806) Crusatte, a member of the party, mistook Captain Lewis for an elk and shot him through the thigh with a rifle. Although seriously injured, Lewis made his way back to the party and with the assistance of Sergeant Gass took off his clothes and dressed his own wounds, "introducing tents of patent

lint into the ball holes." . . . The pain he experienced "excited a high fever" and he "had a very uncomfortable night." "My wounds felt very stiff and soar this morning, but gave me no considerable pain. there was much less inflamation than I had reason to apprehend there would be. I had last evening applyed a poltice of peruvian barks."

Clark, who had been separated from Lewis, joined the party several days after Lewis had been shot and took charge of the treatment of his injured friend. By August 19 he was able to report: "Captain Lewis'es wounds are healing very fast, I am much in hope of his being able to walk in 8 or 10 days." Three days later Lewis had walked a little for the first time, and Clark "discontinued the tent in the hole the ball came out."

On September 9, Clark noted: "My worthy friend Capt. Lewis has entirely recovered his wounds are healed up and he can walk and even nearly run as well as he ever could."

Clark treated an Indian "who had his arm broke and had it loosely bound in a piece of leather without anything to support it."

> He dressed the arm which was broken short above the wrist, supported it with broad sticks to keep it in place, put it in a sling and furnished him with some lint bandages &c to Dress it in the future. . . .
>
> A chief whose wife had an absess formed on the small part of her back promised a horse in the morning provided we would administer to her, accordingly Capt. Clark opened the absess introduced a tent and dressed it with basilicon. I dressed the woman again this morning who declared that she had rested better last night than she had since she had been sick.

The Eye Dispensary and Defective Vision

Defective vision and blindness seem to have pursued the Indians with Achillean relentlessness. Lewis states "soar eyes seem to be a universal complaint among these people" and Clark, "I began to administer eye water and in a few minutes had nearly 40 applicants with sore eyes." The true source of their eye affliction is obscured by a combination of circumstances to which they were exposed conducive to impairment of sight, by the prevalence of disease among them whose complication was inflammation of the eyes and consequent blindness and by the ignorance of successful methods of treatment.

Lewis reports the presence of Neisserian infection and lues among many of the tribes of Indians in the country through which he passed. Ophthalmia neonatorum must have produced its quota of blindness. As syphilis was common among them and was permitted to develop practically without treatment, luetic inflammations and degeneration of the eye were undoubtedly factors in the production of the great impairment of sight recorded by Lewis and Clark.

It is probably correct to assume that trachoma was one of the major causes of the great destruction of vision and wide prevalence of sore eyes among them. While trachoma is essentially an imported disease, it is said to be "as old as the Nile, the simoon, and the desert." Other diseases of such venerable age and power of transmission reached the shores of America and followed the war paths of the Indian into the interior of the continent long before President Jefferson became interested in his "literary pursuit."

It has been comparatively recently that public health officials have obtained some conception of the extent of the prevalence of trachoma in the United States. A survey by the Public Health Service shows the disease exists more or less throughout the country. Indians were found to be almost universally infected and on some reservations 90 per cent had trachoma. It is now known that the disease has been endemic in the Appalachian Mountain region for years.

The severe periodic restrictions in diet practiced by certain tribes of Indians in the region of the Columbia-Missouri Divide due to seasonal scarcity of game and to the fear of their enemies may have caused deficiency of nutrition sufficient to produce inflammations of the eye. Where tribes were compelled to exist on a few dry roots for a considerable length of time the lack of sufficient fat soluble, vitamine A or a very low protein diet, combined with infection, may have brought about disease of the eye similar to xerophthalmia.

Further evidence of ill health among the Indians due to malnutrition is presented in the person of the moribund chief who was cured by the substitution of a diet of fish and flesh for that of roots, a cold bath, several doses of the flour of sulphur and sweating Indians whose diet was largely restricted to roots also had very poor teeth. The latter condition may in part have been due to eating of the roots without the entire removal of the sand.

While Lewis was unfamiliar with vitamines, he was too experienced an observer not to note diseases in the presence of inadequate diet and not to suspect a cause and effect relationship. "I suspect that the confinement to a diet of roots may give rise to all of these disorders, (scrofula, ulcers, loss of the use of the limbs) except rheumatism and sore eyes, and to the latter of these, the state of debility incident to a vegetable diet may immeasurably contribute."

Such physical factors as intense light, foreign bodies, smoke and exposure to wind and dust were important factors in causing inflammation of the eye and impairment of sight among the Indians. Clark in one of his visits to an Indian lodge states, "the Smoke is exceedingly disagreeable and painfull to my eyes." He has also

written his opinion as to the effect of their occupation upon their vision.

I observed an Indian woman who visited us yesterday blind in one eye, and a man who was nearly blind in both eyes. The lost of sight I have observed to be more common among all the nations inhabiting this river (Columbia) than among any people I have ever observed. they have almost invariably sore eyes at all stages of life. the loss of an eye is very common among them. blindness in persons of middle age is by no means uncommon, and it is almost invariable a concammitant of old age. I know not to what cause to attribute this prevalent deficiency of the eye except it be their exposure to the reflection of the sun on the water to which they are constantly exposed in the occupation of fishing. & the snows dureing the winter Seasons in the open countrey where the eye has no rest. . . .

A very singular disorder is taking place amongst our party that of the sore eyes. three of the party have their eyes inflamed and Sweled in Such a manner as to render them extreamly painfull, particularly when éxposed to the light, the eye ball is much inflaimed and the lid appears burnt with the Sun, the cause of this complaint of the eye I can't account for. from its sudden appearance I am willing to believe it may be owing to the reflection of the Sun on the water.

Clark also describes a case of snow blindness and a remarkable cure for it which, in reality, was the application of moist heat.

One Chief of the Mandans returned from Capt. Lewises Party nearly blind, this Complaint is as I am informed Common at this Season of the Year and caused by the reflection of the Sun on the ice and Snow, it is cured by jentilley swetting the part affected by throwing Snow on a hot Stone.

The formula of the eye water that made Clark famous among the Indians is given by Lewis in his report of conjunctivitis among members of his party.

Soar eyes continue also to be common to all of us in a greater or less degree. I use for soar eyes a solution of white vitriol (zinc sulphate) and the sugar of lead (lead acetate) in the proportion of 2 grs. of the former and one of the latter to each ounce of water.

Hygiene

To the modern hygienist health is far more than the mere attainment of physical perfection, the state of freedom from disease, or of being safe and sound. It is that true greatness only completely attainable when the individual makes the most of his physical, mental and moral capacities in his service to humanity. Both Lewis and Clark were healthy. By their accomplishments and by their expressions in their unguarded moments of reflection is revealed the quality of life that made them so fit to "live most and serve best."

Clark, in reply to the felicitations of the citizens of Fincastle and vicinity, radiates health.

It will be a pleasing reflection in future life to find that the expedition has been productive to those advantages of our Country, Geography and science that you are willing to imagine. To respect the rights of humanity has and ever will be the leading principle of my life and no reflection is more pleasing to me than that of effecting the object we had in view with the effusion of so small a portion of human blood. "

Lewis was more temperamental than Clark. He exhibited a slight tendency to moodiness, but his attitude of mind was wholesome. Except for the unfortunate circumstances surrounding his death, history does not record that his mind dwelt more in the valley than on the heights.

This day (August 18, 1805) I completed my thirty first year, and conceived that I had in all human probability now existed about half the period which I am to remain in this Sublunary world. I reflected that I had as yet done but little, very little, indeed, to further the happiness of the human race or to advance the information of the succeeding generations.

I viewed with regret the many hours I have spent in indolence, and now how soarly feel the want of that information which those hours would have given me had they been judiciously expended, but since they are past and can not be recalled, I dash from me the gloomy thought, and resolve in future, to redouble my exertions and at least indeavor to promote those two primary objects of human existence by giving them the aid of that portion of talents which nature and fortune have bestoed on me; or in future to live for mankind, as I have heretofore lived for myself.

WHO WAS FREDERICK TAYLOR?[1]

By SELDEN SMYSER
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EVERY one knows Thomas Edison, knows that he is great and wherein his greatness lies. Most intelligent Americans also know Charles Steinmetz and that he too was great, but wherein his greatness lies is very uncertain with most persons; but Frederick Taylor! Who can place him?

Most people know nothing of him or merely that he was an "efficiency man." Others who are themselves men of large ability and scientific training believe him to have been one of the greatest thinkers of this century. Yet those who agree in believing in his greatness are far from agreeing with each other as to wherein his greatness lies. Others know him to have been an erratic individual who originated ingenious devices for speeding up men at work—methods that especially rewarded the superior and tended very subtly and effectively to break down the one bulwark of the workers—the union.

No other scientist of modern times has been honored by having his special work carried on by a voluntary organization of nine hundred able men united to continue his special work, as Taylor has been honored in the Taylor society. Probably no scientist since the days of witchcraft has been so condemned by having his scientific methods legislated against by a great nation. Yet for a number of years officers of the army or navy of the United States who might use Taylor methods of studying an industrial task in a government plant have been subject to a loss of pay under a law reenacted by congress, session after session.

The man who was the subject of such contradictory views and antagonistic activities has been dead for nearly ten years. Yet, until the appearance of Frank Copley's two volume biography, the material for a broad general view of his methods, accomplishments and fundamental aims has been difficult to attain. Taylor explained himself by activity rather than by words. His activity has so many different aspects and aroused so much and such varied emotions that Frederick Taylor was, and probably will continue for some years to be, a problem.

[1] "Frederick W. Taylor, Father of Scientific Management," by Frank Barclay Copley, 2 vols., 467–472 pp., Harper, $10.00.

Though it will not settle the controversy nor fix the position of Taylor in the development of modern thought and techniques the Copley volumes should do much to lead toward a more definite recognition and appreciation of the actual achievements of Frederick Taylor and much to lead toward a clearer understanding of the nature of his methods and of the philosophical implications of his attitude toward society. A work that has aroused such admiration, loyalty and faith as his must be evaluated. This biography, when taken along with the backward look which is our privilege to-day, should help to a recognition of those tactical blunders of Taylor in his attitude toward the unions which aroused the intense antagonism that so distorted the view of his work and aims. This is easy to see now in looking backward. The blunder was perfectly natural and excusable too, but it robbed Taylor of that reward to which his pioneer work entitled him—the reward of being widely understood and appreciated.

Mr. Copley is rather too apologetic and explanatory, it seems, in treating this matter. He labors too hard, "protests too much, methinks," in proving that Taylor really had the interests of the workers at heart. Taylor cared fully as much, far more, indeed in his later years for the interests of the workers than for those of the capitalists and owners. But far more than for either he cared for development of a new way of doing things in industry. He liked individual workers, but he cared for the workers as a class in much the same way that a New England abolitionist cared for the slaves. Taylor was a scientific genius driven by a great idea. This idea, from being vague, instinctive and antagonistic at first (at the time of his first clash with the lathe men in his effort to break up systematic soldiering), gradually became clearer and clearer as the years went by. The biography shows very plainly the development of this idea in and through Taylor's life and that is just the thing it should do.

The development of implications—philosophical, sociological, scientific and practical implications—of Taylor's work remains to be done and will probably be a gradual process covering several years, for the implications are far more radical, consistent and extensive than will be suspected by any who have not actually studied Taylor's work sympathetically. He himself lacked the power of explaining his methods in writing. He relied rather upon demonstration. He probably was incapable of formulating and systematizing the essential implications of his accomplishments. He thought in terms of actions rather than of abstract ideas.

Taylor was a true radical in his aims. Lenin was not more so. One would not have changed society more radically than the other.

But the method—there is the difference! They are as different as up and down. Both would have given us a social order believed to be shaped by science and pure intellect. Lenin attacked and changed the whole social order of his country according to doctrinaire principles. Taylor attacked the little details of industrial and social processes. He had very few doctrinaire principles in his creed, and these were principles of method only. Taylor believed that truth for the guidance of a man's conduct in reconstructing the social order is to be attained chiefly through life-size continuous experimentation conducted under normal industrial and social conditions but with all the accuracy of a research laboratory. Second: All traditional ways of doing things—the materials, tools, techniques and organization—however well established are to be suspected of being wrong and wasteful until they have been tested and verified by the experimental method as developed by modern science and adapted by the Taylor group. Lenin would begin by revolution and reconstruction of the social order itself. Taylor would begin the reconstruction of society by carefully investigating all the little details of social practice in industry, in government and commerce—by measuring, recording, calculating and discovering just where there is error and how great the error, and lastly how that error can be systematically eliminated from the practice of the shop and from the habits of the individual worker and from life.

No sociologist who believes in a positive method—a thoroughly objective method—has ever even proposed so clear a social program as Frederick Taylor demonstrated in large scale experiments—though he could not explain fully to men untrained in industry. He is the great successor of Compte and the precursor, perhaps, of a school of practical sociologists that is only beginning to be clearly conscious of itself.

Mr. Copley, a layman, has done better, it seems to the reviewer, than an engineer would have been likely to have done in writing a biography for the general reader. He has not in general shirked or treated vaguely the various technical matters involved in Taylor's career, but after careful study has made them clear to the lay reader. His admiration for his subject is great, but he is not undiscriminating. His careful, intelligent work, by which he has traced the development of Taylor's ideas, should start a period of more detached interpretation of the Taylorean program. For a new philosophical and social program is necessarily involved in Taylor's attitude and practice. It is one of extreme radical empiricism—of pragmatism raised above the level of philosophical discussion to the level of continuous cooperative large scale experimentation and reconstruction.

THE STATE OF SCIENCE IN 1924

THERMIONIC VALVES[1]

By Professor J. A. FLEMING, F.R.S.
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EARLY DISCOVERIES

THE history and development of the thermionic valve is a striking example of the important industrial applications that sometimes follow from discoveries which take place in the course of purely scientific researches. In 1883 Edison sealed a metal plate into the ordinary electric incandescent lamp between the legs of its carbon filament. This plate was carried on a wire sealed through the wall of the glass bulb. He noticed that when the filament was made incandescent by a direct current sent through it, simultaneously a small electric current could be detected in a circuit between the *positive* terminal of the filament and the wire carrying the metal plates; on the other hand, no current could be detected between the *negative* end of the filament and the plate. This phenomenon was called the "Edison effect," but no explanation of it was given by its discoverer, nor was any practical use made of it at the time.

Investigations on the nature of the Edison effect undertaken by the writer in 1883 and onwards showed that the effect was connected with the projection in straight lines of particles from the filament; further, these projected particles carried a charge of negative electricity and could convey negative electricity from the filament to the plate, but not in the opposite direction. A further step in advance was made about 1897 by Sir Joseph Thomson, who showed that the chemical atoms of matter, which at the time were thought to be incapable of being divided, contained still smaller atoms of electricity, now called *electrons*. Soon afterwards, it was ascertained that the incandescent filament of the ordinary electric lamp is a prolific and continuous source of electrons, which are sent out in all directions.

About 1897 the application by Senatore Marconi of Hertzian electric waves for the purposes of wireless telegraphy began to create public interest. For detecting these waves he first used his im-

[1] Prepared for the Hand-book to the Exhibit of Pure Science arranged by the Royal Society for the British Empire Exhibition.

proved form of the coherer of Branly and Sir Oliver Lodge. It was, however, rather capricious and somewhat difficult to manage, and Marconi soon replaced it by his magnetic detector in 1901.

The Thermionic Valve

In Marconi's system of wireless telegraphy, the electric waves are generated by creating powerful vibratory currents of electricity in an aerial wire. The electric oscillations in this wire produce in surrounding space an electric wave which travels outwards with the speed of light, *viz.*, 186,000 miles per second. When these waves cut across another similar wire, a receiving aerial, they create in it feeble electric vibrations of the same type.

Now, if means could be found of converting the very rapid alternating movements of electricity in the receiving circuits into a uniform motion of electricity in one direction, it would then be possible to detect them, and therefore the electric waves, by the use of the telephone or galvanometer as in ordinary telegraphy, without the use of a coherer. The vibrations of electricity in wireless telegraph aerials are, however, very rapid, even up to a million per second, and none of the devices for "rectifying" or converting slow alternating electric currents into direct currents are of any use. The Edison effect, however, seemed to offer a solution of this difficulty, and in 1904 the writer found that if a metal cylinder was placed around the filament inside the vacuous bulb of an electric lamp carried on a wire sealed through the bulb, the appliance could "rectify" and therefore detect by the aid of a telephone or galvanometer these feeble high frequency oscillations. They can not directly affect a telephone because of their rapid reversals of directions, but the instrument above described acts as a *valve* when placed in the path of the oscillations and converts them into motions of electricity in one direction, in virtue of the fact that negative electrons are passing in the vacuous space only from the filament to the surrounding metal cylinder.

The apparatus was therefore termed an *oscillation valve,* and afterwards a *thermionic valve*. Later, in 1909, tungsten was used as the material for the filament in place of carbon, as it withstands a higher temperature and emits more electrons.

The above described two-electrode or hot and cold electrode thermionic valve was soon extensively adopted as a means of rectifying and detecting electric oscillations and detecting wireless waves.

In the spark system of wireless telegraphy then exclusively used, the waves come in little groups of 20 or 30 with longer intervals of

time between the groups. The Fleming valve rectifies the groups of oscillations produced in the receiving aerial into short gushes of electricity in one direction, and when these are passed through a telephone they give rise to a more or less musical sound which can be cut up by a key in the transmitter into the *dot* and *dash* or short and long sounds of the Morse code.

Developments of the Fleming Valve

In 1907 an addition was made to the Fleming oscillation valve by Dr. Lee de Forest, in the United States. Dr. de Forest introduced into a low vacuum valve a grid or zigzag of wire between the filament and the plate. This started a new line of development, and it was found that, if a cylinder of metal gauze or spiral of wire was introduced into the hard or high-vacuum Fleming valve between the cylinder and the filament, it enabled the device to act as an amplifier of oscillations, as well as a detector, so that very feeble high frequency oscillations could be magnified five or ten times by its aid. This suggestion was developed practically by the resources of the Western Electric and General Electric Companies, of America.

This modified form, then, became known as a *three-electrode valve,* and is sometimes called for shortness a *triode,* or other trade names. To employ it as an amplifier, a high-tension battery giving, say, 40 to 140 volts, is connected with its negative pole joined to the filament and its positive pole to the plate. A torrent of electrons is then forced from the filament, through the holes in the grid or gauze to the plate. If, however, a feeble electrification is given to the grid, positive or negative, it increases or decreases this electron current. The grid potential electrification can be obtained from any two points on a circuit in which a feeble high-frequency current flows, and the variation of the plate current of the valve will follow the variations of its grid potential. A number of such valves can be used in series and interconnected by suitable induction coils or transformers, and the plate current variations in one valve be made to create changes of grid potential in the next valve. By a series of such coupled amplifying valves, feeble electric oscillations can be magnified in any required proportion. It is the invention of this detector, comprising a series of amplifying valves, which has given us a detector of electric oscillations so enormously sensitive that has enabled us to signal half round the world.

The Thermionic Oscillation Generator

The thermionic valve, in its two- and three-electrode forms, possesses the power not only of rectifying and detecting electric

oscillations, but also of creating so-called continuous or undamped oscillations. This discovery at once rendered possible radio-telephony on a large practical scale, whereas it had previously only been an occasional feat of experts. The proper coupling through a transformer of the grid and plate circuits results in the production in these circuits of self-sustained oscillations by energy drawn from the plate circuit.

During and since the war, improvements have continually been made in the construction of large generating valves. Beginning originally with very small powers of a few watts in valves with bulbs like incandescent lamps, very large valves in glass bulbs, the size and shape of Rugby footballs, yielding an output of six or seven kilowatts, are now made. Valves of 10 to 20 kilowatts output or more have been made with bulbs of silica. The most recent advance in this direction has come to us from the United States. A method of making high power valves with bulbs partly of glass and partly of copper has been developed by the Western Electric Company, of America, based on the fact that a copper tube with a sharp edge can be welded to a glass tube. In large valves a source of trouble is the heating of the metal cylinder by the bombardment of the electrons. In the metal bulb valves the copper part forms also the anode cylinder, and it can be kept cool by immersion in water.

Large generating valves of 10 to 100 kilowatts have been made in this manner, and the General Electric Company, of America, are said to be preparing a thermionic generating valve of the two electrode or Fleming type with an output of 1,000 kilowatts or 1,300 horse-power. If this can be done, large thermionic valves will replace high frequency alternators entirely in long distance wireless stations. Already Marconi's Wireless Telegraph Company have a valve panel of 56 large glass valves in their Carnarvon Radio Station, with which communication is made direct to Australia. The present public wireless telephone broadcasting stations in Great Britain employ large valve generators in their transmission plant.

Modern Wireless Telephone and Telegraph Valve Receivers

The improvements made in the construction of the thermionic valve and the close study of its action imposed by the necessity for developing wireless telegraphy and telephony during the war have given us an extraordinarily sensitive and easily managed detector of electric waves, and the advent of wireless telephone broadcasting has created a novel trade in the manufacture of these valves for generating, amplifying and detecting electric waves.

In the receiving valve most commonly used, a straight filament of tungsten, or thoriated tungsten, or else platinum-iridium, coated with oxides of barium and strontium, is used. This is surrounded by a spiral wire forming the grid and by a nickel or molybdenum cylinder forming the plate. The ends of the filament, grid and plate are connected to pins on a cap, so that the valve can fit into a socket like an electric lamp.

In modern wireless telegraph receivers, one or more valves are used to amplify the oscillations; one to detect, and one or more to amplify the rectified currents.

Valves of this type were made to the number of three or four million during the war (1914–1918) and are manufactured now by the hundred thousand per annum for broadcasting purposes.

The Thermionic Telephone Repeater

An additional service the thermionic valve renders is as a perfect telephone relay or repeater. Telephone electric speech currents are enfeebled by flowing along a telephone wire, and for long distance working very thick and therefore costly wires were required. Thermionic amplifiers can, however, be inserted in the line to reenforce the currents.

By the use of these repeaters, telephonic speech is now transmitted right across the continent of America (4,000 miles), and they are now much used by the British post office. For shorter distances a great economy in copper can be obtained by their use. In short, the thermionic valve has effected a revolution in ordinary telephony just as it has made possible wireless telephony.

THE ORIGIN OF SPECTRA

By Professor A. FOWLER, F.R.S.
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Spectra are of two kinds—band spectra and line spectra. Band spectra are very complex and originate in molecules. Line spectra are of varying degrees of complexity and have their origin in atoms. All compounds which can be excited to luminosity without decomposition give rise to band spectra, but the application of sufficient energy results in the appearance of the spectra of the component elements. Similarly, an element which gives a band spectrum in its molecular form will yield a line spectrum when the energy which excites it to luminosity is capable of dissociating the molecules into their constituent atoms. For example, the band spectrum of oxygen

or nitrogen may be produced by the passage through the gas of uncondensed discharges from an induction coil, and the line spectrum by the passage of the more intense condensed discharges.

Some of the earlier workers in spectroscopy were urged on by the idea that a spectrum must provide a clue to the structure of the atoms of molecules which produce it, and probably also to the mechanism of radiation. The majority of spectra, however, are exceedingly complex, and it was evident that the first step towards the elucidation of these problems was to discover the laws governing the distribution of the lines or bands, so that the essential features of a spectrum might be expressed in a simplified form. Theories of the origin of spectra, and of the constitution of atoms, are thus largely based upon investigations of regularities in the arrangement of spectral lines and bands.

In the discussion of such regularities, the position of a line is most usefully indicated by its "wave-number," or number of waves per centimeter. Thus, if λ be the wave-length in vacuo, expressed in Ångström units (1 Ångström unit $= 10^{-8}$ cm), the wave-number, denoted by ν, is given by $10^8/\lambda$. These wave-numbers are strictly proportional to the oscillation frequencies.

Line Spectrum of Hydrogen

The simplest of all line spectra is that of hydrogen. In the most familiar part of this spectrum, beginning with a line in the red, the lines follow each other with gradually diminishing intensities and at gradually diminishing distances from each other, so that they approach a definite limit in the near ultra-violet. Lines arranged in this manner constitute a "series," and it was discovered by Balmer in 1885 that the lines of the hydrogen series could be included in the simple formula

$$\lambda = 3646.14\, m^2/(m^2 - 4),$$

where m takes successive integer values ranging from 3 to infinity. In terms of wave-numbers, the formula becomes

$$\nu = 27419.6 - 109678.3/m^2.$$

There is another series of hydrogen lines in the extreme ultraviolet, called the Lyman series from the name of its discoverer, and others in the infra-red, each of which is generally similar in structure to the Balmer series. The entire spectrum is accurately represented by the simple formula—

$$\nu = N/\left(\frac{1}{m_1^2} - \frac{1}{m^2}\right)$$

where $m > m_1$ and $N = 109678.3$. This number was found by Rydberg to appear in the formulae for other spectra, and is called the Rydberg constant. In the formula for hydrogen, the Lyman series

is given by putting $m_1 = 1$, $m = 2, 3, 4 \ldots$; the Balmer series when $m_1 = 2$, $m = 3, 4, 5 \ldots$; and similarly for the other series in the infra-red.

Series in Line Spectra

Series which are of generally similar character to those of hydrogen were found by Rydberg and by Kayser and Runge to occur in the spectra of other elements. In the general case, several associated and overlapping series occur in the same spectrum, and are distinguished by the names principal, sharp, diffuse, fundamental and super-fundamental series. Each of such series may be represented approximately by Rydberg's formula

$$\nu = N\left[\frac{1}{(m_1+\mu_1)^2} - \frac{1}{(m+\mu)^2}\right]$$

where m_1 and m are integers, and μ_1, μ are constants special to each series. More exact representations of the series are given by including correcting terms in the denominators.

The formula representing a series thus consists of two parts, the first of which indicates the end or "limit" of the series, while the second is a variable part dependent upon a sequence of integers. The position of an actual spectral line consequently appears as the difference of two terms, one of which is the limit of the series to which it belongs. The word "term" has thus come to have a special meaning in spectroscopy; it signifies a wave-number which does not represent a spectral line in itself, but only when combined with another wave-number. The limit of a series is a term of one of the other series. The "combination principle" of Ritz expresses the fact that, with certain restrictions, terms from any one series may be combined with terms from other series to produce spectral lines.

Series, and their constituent terms, are now usually represented by abbreviated notations, of which the following are typical:

Principal series	$1s$—mp
Sharp series	$1p$—ms
Diffuse series	$1p$—md
Fundamental series	$2d$—mf

In each case the term on the left represents the limit of the series, and that on the right the sequence of variable parts corresponding to successive values of m. It should be further observed that series may consist of singlets, doublets or triplets. In a doublet system the p term has two values, and the d and f terms may also have two values. In a triplet system, the p, d and f terms have three values, and a singlet system is also associated with the triplets.

Elements of Group I in the Periodic Table of Elements, including the alkali metals, give doublet series, those of Group II triplets and those of Group III doublets. Among the elements of Group IV,

silicon at least includes triplets, and there is thus an alternation of doublets and triplets in harmony with odd and even valencies. Recent investigations have shown still greater complexities, in the terms relating to the later groups of elements, but even and odd multiplicities have been found to alternate throughout all the successive groups of the Periodic Table.

Origin of Spectra and the Quantum Theory

In view of the results of the analysis of spectra, it is clear that a successful theory must first account for the terms which give rise to the spectral lines by their combination. The terms have, in fact, a more immediate physical significance than the lines themselves. In the now well-known theory of Bohr, following Rutherford's conception of atomic structure, an atom is supposed to consist of a heavy positively charged nucleus, with a number of electrons circulating round it. In the normal state, the atom is neutral, and the number of external electrons is equal to the number of units of positive charge of the nucleus. When the atom is unexcited, the electrons may be regarded as traversing orbits more or less similar to those of planets or comets traveling around the sun, and obeying similar laws, with the difference that in the case of atoms the controlling forces are electrical.

The nature of the theory may be best indicated by reference to hydrogen, which has the simplest possible structure, each atom consisting of a positive nucleus of unit mass and unit positive charge and a single electron. When the atom is disturbed, the electron may temporarily traverse a larger orbit, but it is not free to occupy any orbit whatsoever, but only those in which the energy has definite values determined by the Quantum Theory. When the electron traverses one of these orbits, there is no radiation, and the atom is said to be in a "stationary" or non-radiating state. A spectrum line is produced when the electron returns to a smaller permissible orbit. Only one line is produced in a single transition, and the actual spectrum of many lines represents the integrated effect of a large number of transitions between the different permissible stationary states. The energy radiated during a transition is always a single quantum $\varepsilon = h\nu$, where h is Planck's quantum of action and ν is the frequency of the radiation. The frequency of the emission, and therefore the position of the corresponding spectral lines, is thus dependent upon the difference of energies of the initial and final orbits. Exactly what happens during a transition is not yet understood. The "terms" of the spectra which have already been considered are accordingly proportional to the energies in the corresponding stationary states.

On this theory, Bohr has obtained a formula for the hydrogen spectrum which is identical with that derived from observations, within the limits of accuracy with which the quantum of action and the charge of the electron have been determined. The theory has also been extended, with remarkable success, to the explanation of the complex structure of the spectral lines, and of the effects of external magnetic fields.

Atoms of elements other than hydrogen are more complex in structure. A helium atom has a nucleus of mass 4 and positive charge 2 units, and two external electrons. The atom of lithium has three external electrons, and a nucleus with a treble positive charge, and so on throughout the table of the elements, the nuclear charge being equal to the "atomic number" of the element. The spectra, however, do not necessarily increase in complexity with increase of atomic number. In each case, the spectrum is considered to be produced by a single one of the external electrons, interacting with the rest of the atom, which, in the main, will have a single positive charge Apart from a small effect due to the mass of the nucleus, the series constant for all elements is, accordingly, the same as that for hydrogen. Owing, however, to the presence of one or more electrons in the atomic residue, the possible stationary states are more numerous than in the case of hydrogen, so that several series occur in the same spectrum. The theory, however, is not sufficiently developed to permit the actual calculation of the positions of spectral lines other than those arising from a nucleus and a single external electron.

Arc and Spark Spectra

Spectra produced in the electric arc and the electric spark, though mostly showing some lines in common, usually exhibit important differences. Lines which are intensified, or only appear, in the spark are called "enhanced lines." Similar differences also occur in the spectra of gases as the energy which excites them to luminosity is increased.

The distinction between arc and spark spectra has become more definite in the light of Bohr's theory. Lines which occur in the arc, excluding those which are stronger in the spark, form series which are characterized by the Rydberg constant N, as already explained, and are attributed to neutral atoms. Enhanced lines, on the other hand, form series which involve the constant $4N$, and are attributed to ionized atoms; that is, to atoms which have lost an electron. The simplest example is afforded by ionized helium. When a helium atom has lost an electron, it resembles the hydrogen atom, except that the nucleus has a greater mass and has a double positive charge.

The spectrum is correspondingly similar to, but not identical with, that of hydrogen; it may be represented by the simple formula

$$\nu = 4N'\left(\frac{1}{m_1^2} - \frac{1}{m^2}\right)$$

where N' is slightly larger than N on account of the greater mass of the nucleus as compared with that of the hydrogen atom. This theoretical prediction agrees completely with the actual observations of the spectrum; the important line of ionized helium at $\lambda 4,686$, for example, is the first member of the series given by putting $m_1 = 3$.

The spark spectra of elements other than helium show series which differ from those of arc spectra only in having a four-fold value of the series constant; they are also explained in a general way by an extension of the theory similar to that made in the case of arc spectra. It should be noted that in accordance with the so-called "displacement law," the spark spectrum of an element is of the same type as the arc spectrum of the element which precedes it in atomic number.

Spectra of Highly Ionized Atoms

Bohr's theory further indicates that atoms which have lost two electrons, or are doubly-ionized, may be expected to yield series which are characterized by the series constant $9N$. Trebly-ionized atoms would give series for which the constant would be $16N$, and so on. Series with $9N$ for the constant have, in fact, been established for aluminium by Paschen, whilst both $9N$ and $16N$ series have been traced by Fowler in silicon by the action of strong discharges through silicon fluoride. The chief lines of highly-ionized atoms are of necessity in the extreme ultra-violet, and can only be observed by the use of the vacuum spectrograph. The lines which appear within the ordinary range of observation belong to secondary series, but are, nevertheless, sometimes well-developed.

Important contributions to the theory of spectra have also been made by investigations of resonance and ionization potentials. In these experiments a gas or vapor is bombarded by electrons, the speed of which can be regulated by an adjustable electric field. Energy from an impacting electron is thus transferred to the atom, and is subsequently radiated on the return of the atom to its normal state. The energy required to develop certain spectral lines, or the complete spectrum, has thus been directly measured and has been found to be in agreement with that deduced from Bohr's theory.

The observational evidence is thus entirely consistent with Bohr's theory, and continued researches on spectra in the directions outlined may be expected to aid in the development of the theory, and in the deduction of the normal structure of the atoms of additional elements.

BAND SPECTRA

The appearance of a band series is in several respects very different from that of a line series. The constituent lines are usually much more numerous and much closer together; further, although there is a certain resemblance to line series in the crowding together of the lines towards a "limit," series lines invariably fade out before the limit is reached, whilst band lines often reach the limit, and may even have their maximum of intensity in its neighborhood, so that the resulting "heads" are frequently very conspicuous features of the spectrum. Again, the law according to which the lines are arranged is quite different from that of the lines series, being of the form $\nu = A + Bm + Cm^2$, where A, B and C are constants and m is the number of the line in the series reckoned from any convenient starting point. The arrangement of the heads relative to one another may also be expressed by a formula of this type, which is the analytical representation of a parabola.

Experimental evidence has persistently related band spectra to molecules, but only in recent years has any detailed theoretical explanation been achieved. The quantum principles which have proved so strikingly successful in the elucidation of the problems of atomic radiation are no less applicable to molecules. But the case is considerably more complex, for in addition to the movements of the electrons within the molecule, we have to take into account the vibrations of the atomic nuclei and the rotation of the molecule as a whole. The total energy (W_1) associated with all these motions is characteristic of the particular state of the molecule at the moment, and if a change occurs in one or more of them the total energy will assume a new value (W_2). Then, exactly as for line spectra, we find that the frequency emitted (considering the case of a decrease of energy, *i.e.*, of radiation) is given by

$$\nu = \frac{W_1}{h} - \frac{W_2}{h}.$$

It is the greater variety of possible states of a molecule as compared with an atom which gives rise to the greater complexity of a band spectrum as compared with a line spectrum.

The present position is that, while the Quantum Theory has succeeded in accounting for all the main features of band structure, as, for example, the parabolic law mentioned above, there are many details as yet unexplained. Even the simplest bands hitherto studied, those due to helium, present problems of this kind, and in the case of the more massive and complex molecules, many difficulties present themselves. But it seems probable that these very discrepancies will, in the light of further study, provide the material for valuable extensions of our theoretical knowledge.

THE PREVENTION AND CURE OF RICKETS[1]

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RICKETS, or rachitis, is one of the most important diseases of infancy and childhood. In the rachitic baby the bones fail to become calcified; consequently, they remain so soft that they are easily bent out of shape The result, in many cases, is a deformity, such as knock-knee, bow leg, hunch back or lateral curvature of the spine.

Rickets is so common that most babies experience a mild degree of it at some period, especially in winter. If the baby is well cared for he will outgrow it completely. Rachitis is not in itself fatal. But, because it weakens the body, and because it becomes complicated with other diseases, it is an important cause of infant mortality. It is a disease of growth: the youngest children are the most liable to it; the prematurely born suffer most of all. Consequently, if the rachitic child survives to a mature age, when he ceases to grow, his active rickets disappears, but it may leave him permanently deformed or even dwarfed.

In order to understand these phenomena, one must know how bones grow. The embryonic bone is soft. It becomes hardened by calcification, that is, by deposit of mineral matter within the cells. The mineral matter contains a number of different salts in significantly constant proportion, including about 85 per cent. calcium phosphate. Thus it can be seen that calcium and phosphorus are the two elements peculiarly needed for the hardening of bones. Even after a bone has become calcified it is capable of increasing in size and changing in shape. One fact which enables it to do this is that while new lime salts are being deposited in the bone the old ones are being continually redissolved. Moreover, each bone serves as a storehouse from which lime may be withdrawn to supply other bones or to serve other uses—and lime has many other uses in the body besides bone-building. A considerable quantity of calcium and of phosphorus is absorbed daily from the food, and a considerable quantity is excreted daily in the urine and the feces. Thus there is a continuous metabolism of calcium and phosphorus.

[1] From the Laboratory of Biophysics of the Cancer Commission of Harvard University.

Rickets is a disorder of this metabolism. During active rickets, not only is there insufficient deposit of calcium phosphate in the bones, but in certain cases a bone which was once hard may actually become soft again, as the lime salts in it are dissolved away.

The body needs calcium and phosphorus not only for bone-building but also for a great many other functions. Each of these elements is a prime necessity of life. Each needs to be present in the blood in certain minimum amounts. And each needs to be present in a certain proportion or "balance" with relation to other elements. Disturbance of this balance upsets a great many different functions, among which we shall mention only one, *i.e.,* the action of the nervous system. Potassium and sodium (monovalent cations) increase the irritability of the nervous system; calcium ions decrease the irritability. Consequently, if calcium is deficient in the blood of a baby, the result is a certain hypersensitivity named "tetany," manifested in convulsions. Many babies who have rickets have convulsions also, both being due to calcium deficiency. A convulsion can usually be terminated by injection of a calcium salt into the veins. But this of course does not cure the disease. To cure the tetany or to cure the rickets the mineral metabolism must be brought back to normal.

Before speaking of the prevention and cure of rickets, we wish to speak of preliminary matters that will help toward an understanding of the problem. But for the sake of clearness it will be best to anticipate and to say at this point briefly that we now know two methods of treatment which prevent or cure rickets. One method is to supply a diet rich in vitamin D, a substance which has been found most abundantly in cod liver oil, but also in certain other fats and in green vegetables. The other method is to irradiate the body with ultra-violet rays.

Knowledge of these two preventives enables us to explain the very interesting facts in regard to the occurrence of rickets. The disease is found only in civilized communities, especially in large cities, where children are kept too much indoors, and are fed on a diet deficient in green vegetables and in other sources of vitamin D. In farming communities the disease is rare or unknown Among savage peoples the children are, in general, free from it, because they are exposed to sunlight every day. The Eskimo baby is free from it, even though he lives in a dark hut, because he is suckled by a mother who consumes great quantities of animal fat and oil.

The seasonal occurrence also is explicable by its relation to vitamin D and to ultra-violet rays. For rickets is incurred mainly

in winter, when the baby receives too little sunlight and the mother receives too little green food.

The incidence of rickets among animals is similar to that among men: wild animals are free from it; domestic animals are subject to it. The disease of chickens known as "weak legs," which causes great losses to poultrymen, is either a form of rickets or something very similar to it. The symptoms are typical. At the age of three weeks the chick shows lack of vigor. At five weeks it has fully developed the "weak leg" condition: the toes are crooked, the nails long and curled; the legs are so weak that the chick can not stand up, it crawls to its food with feet and wings, using the wings as a pair of crutches. Its bill is soft, and its plumage ruffled. X-ray photographs reveal a lack of calcium salts in the bones. If the disease is allowed to reach this stage the chick usually dies.

Steenbock has shown that the disease of pigs which the farmers call "rheumatism," and which causes serious losses annually, is really rickets. Dogs, monkeys and rats also are known to suffer from rickets. The susceptibility of the rat is specially important, because rats are the most convenient animals on which to experiment, and a large number of experiments have been tried on them. Without these experiments, the knowledge which we now have of rickets and its cure would have been quite impossible.

The investigator of rickets has had to contend against great and peculiar difficulties. The difficulty of the subject is proved by the amount of research work that has been done on it. For three centuries such research has been continued. The original account of the disease was written by an English physician, Glisson, in 1650. From that day to this the number of investigators has increased at an accelerated rate, so that to-day a great many scientists are working simultaneously on various aspects of the problem. E A. Park,[2] in a review of recent investigations upon "The etiology of rickets," cites 160 papers selected from the vast literature of the subject. There have been a dozen important theories as to the cause and cure of rickets. We shall mention only a few of them.

One theory was that there is a rachitic diathesis which is directly inherited. Statisticians tested this hypothesis, seeking out the family history of cases of rickets, and they did succeed in proving that the disease tends to run in families. But this is due to the fact that all members of a family are generally subject to the same living conditions, including matters of diet, sunlight and general hygiene. Experiments indicate that in a species of animal which is susceptible to rickets the disease can be produced in any in-

[2] E. A. Park, *Physiol. Reviews*, Vol. 3, p. 106, 1923.

dividual and it can be cured in any individual, under suitable experimental conditions. Consequently, if there is any difference between families, in susceptibility to rickets, it must be so slight as to be negligible.

While mentioning that so many theories have been held, it will be interesting to mention one that has not been held. No physician or scientist has supposed that rickets could be cured by drugs. A drug may be defined as a medicine which is not a food nor a natural constituent of the body. In looking through a considerable literature on rachitis, extending back into the nineteenth century, and some of it into the eighteenth century, we have found no mention of drugs. The literature mentions only sunlight, fresh air, exercise and other matters of hygiene; lime, phosphorus and various other items of diet, chiefly those that contain vitamin D; and certain endocrine glands, especially the parathyroid glands, which, of course, are natural constituents of the body. Physicians have recommended drugs for some of the complications of rickets, such as constipation; they have not thought that drugs could cure the rickets itself.

One theory was that rickets is caused by deficiency of calcium or of phosphorus in the diet. This was a very natural supposition, but, in practice, rickets is seldom, if ever, due to this cause. It is true, of course, that the disease can not be cured without an adequate supply of these two elements in the food, for without them calcium phosphate can not be deposited in the bones. This was known to our grandfathers, who gave their children milk and lime water and "sirup of hypophosphites." But our grandfathers were familiar also with the puzzling fact that even when lime and phosphorus are supplied abundantly in the food, yet calcium phosphate may fail to be deposited in the bones. They knew that rickets is due, not to any lack of lime and phosphorus in the food, but to the patient's incapacity for making use of these elements. In our day we call this a derangement of metabolism. But a complete explanation of it seems about as far away as ever. It is difficult to learn much about the chemical behavior of calcium and phosphorus in the interior of the body.

It is known that the endocrine or ductless glands are wonderful regulators of metabolism, and they probably exert an important influence on the metabolism of calcium. The different endocrine glands produce different effects, and the healthy functioning of the body depends upon the maintenance of a proper balance between the various glands. In particular, it is believed that the thyroid glands promote the elimination of calcium. Excessive

thyroid activity, as in exophthalmic goiter, results in an abnormally low amount of calcium in the blood, and this causes nervous irritability in the goiter patient, as it does in the child afflicted with tetany. But the parathyroids antagonize the action of the thyroids, causing calcium to be retained in the tissues.[3] Feeding parathyroid gland to the patient is beneficial in some cases of goiter and of tetany and of other disorders. It was thought at one time that rickets also could be prevented or cured by parathyroid therapy, but when this theory was tested in practice it was not a success. The endocrine glands are not the sole regulators of mineral metabolism, and it has been necessary to search for some other regulator which will prevent and cure rickets. This search has been rewarded by the discovery of two such regulators, one being vitamin D, and the other, ultra-violet radiation.

Vitamin D

From a remote antiquity, among the fishermen of Norway, cod liver oil has been used both externally and internally as a cure for rheumatism. In 1771 it began to be used by English doctors for the same purpose. It was prescribed for rickets in the first part of the nineteenth century, at least as early as 1839. At first the physicians supposed that the oil simply supplied a fat that was more easily digested and absorbed than other fats. Yet even a hundred years ago they noticed that cod liver oil, taken by the spoonful, can produce in the patient an increase in weight which is out of all proportion to the small amount of oil that has been taken. This observation gave them an inkling of the fact that there is in the oil a growth-promoting factor, the factor which is now known as vitamin A. We need not review the history of the discovery of vitamins, because it has been reviewed already in this journal.[4] The remarkable peculiarity of vitamins is that they are present in the diet only in minute quantities, yet these minute quantities are vitally important. Due to this peculiarity, the vitamins escaped detection for a long time, and it is only within the last few years that scientists have distinguished different vitamins and have given to each a name and an epithet; as A, the growth-promoting, also called the antixerophthalmic; B, the antineuritic or antiberiberic; C, the antiscorbutic; D, the antirachitic. Vitamins A and D are both found in cod liver oil, but the discovery of D is very recent.

[3] H. W. C. Vines, "The Parathyroid Glands in Relation to Disease." London, 1924.

[4] B. W. Kunkel, "Calories and vitamines," SCI. MONTHLY, Vol. 17, p. 361, 1923.

Mellanby, of Cambridge, England, proved that there is an antirachitic factor, but he did not succeed in distinguishing it from vitamin A. In 1918 he published a preliminary report of his experiments on nearly 500 puppies. His method was: First, to discover experimentally a diet which was sure to produce rickets in any puppy; then to vary one constituent at a time and observe the effect. Each diet was fed to certain puppies for a long time —many months—in order to make sure whether it would produce rickets or not. Mellanby found that the antirachitic foods are in general those that contain vitamin A, cod liver oil being the most potent of them all. He was inclined to believe that vitamin A and the antirachitic factor are identical, but he was careful not to state this positively. Evidence against the supposed identity was found in the fact that butter-fat promotes growth and cures xerophthalmia but is of little use to prevent rickets. Of coconut oil the reverse is true: it can prevent rickets, but can not promote growth nor prevent xerophthalmia. After much study of the problem, E. A. Park and his associates at Johns Hopkins found that by oxidizing cod liver oil to a certain limited degree they could destroy the growth-promoting and antiophthalmic properties of the oil without destroying its antirachite value. That is to say, vitamin A was destroyed, while the antirachitic factor was left intact. The latter, then, is distinct from vitamin A, and it is now generally known as vitamin D.

Vitamin D has not yet been isolated; no man has ever seen it. But in 1924 Casimir Funk and two collaborators succeeded in getting from cod liver oil a concentrate which is only 0.0001 of the mass of the original oil, yet it contains all the vitamins, both A and D. This concentrate was tested in experiments on 300 rats, and proved to be preventive and curative of rickets. It was then given to the babies in a certain nursery in New York City, in 1-grain sugar tablets, each tablet being equivalent to a half teaspoonful of cod liver oil. Extracts of cod liver oil have been on the market for a great many years, but some of them are probably worthless.

It seems probable that vitamins A and D are both formed by green plants, for their own use, with the aid of the ultra-violet rays of sunlight. When the green leaves are eaten by an herbivorous animal, the vitamins pass from the digested leaves into the blood of the consumer. If the herbivorous animal is eaten by a carnivorous one, the vitamins are passed on into the blood of the latter. The sunlight that falls upon the vast area of the ocean is utilized by myriads of marine algae to form their vitamins. In

some of these algae, under the microscope, drops of oil can be seen. When the oil is extracted from a mass of the algae, it is found to have the characteristic odor of fish oil. This oil is probably the original source from which all the animals of the ocean derive—either at first hand or at second hand—their supply of vitamins A and D.

When an animal takes in more of vitamin D than is needed for immediate use, the surplus is stored. Vitamins A and D, both being fat-soluble, are stored in an oil in the liver. That explains why cod liver oil is so rich in these two vitamins. In birds, a good supply of the antirachitic factor is stored in the yolk of the egg, for consumption by the young bird before it hatches. Consequently, yolk of egg is a good preventive of rickets, and its use is recommended even for very young infants. A young mammal is supplied with vitamin D before birth from the mother's blood, and after birth from the mother's milk, and it stores part of this supply for future use. Thus the normal animal begins life with a good reserve store of vitamin D. This is one of the sources of difficulty in experiments; for when the experimenter puts an animal on a rickets-producing diet, the animal may show no effect for a long time, because it is utilizing its own reserve store of the antirachitic factor. Human milk is richer in vitamin D than cow's milk. Hence, breast-fed babies are less liable to rickets than those that are artificially fed. But the amount of vitamin D in the milk of any species depends largely on the amount of green food eaten before the milk is secreted.

Certain experiments[5] on rats indicate that vitamin D functions as a "regulator" of mineral metabolism. When rats are kept, without vitamin D and without ultra-violet radiation, on a diet containing very little calcium, the amount of calcium in their blood is found to be below normal. If now cod liver oil is added to the diet, even though the amount of calcium in the food is not increased, the percentage of calcium in the blood rises nearly or quite to normal. Under these conditions the organism manages to make very economical use of the small amount of calcium supplied to it. Experiments with low phosphorus give similar results. On the other hand, if calcium and phosphorus are supplied in excessive amounts, and cod liver oil is given, the concentration of these two elements in the blood does not rise above normal. Manifestly, there is some well-adjusted mechanism which "regulates" the mineral metabolism.

[5] B. Kramer and J. Howland, Johns Hopkins Hospital Bulletin, Vol. 33, p. 313, 1922.

Ultra-violet Rays

If an animal is given no vitamin D in its food, but the surface of its body is irradiated with ultra-violet rays, the result is that the concentration of calcium and of phosphorus in the blood is regulated, and rickets is thereby prevented or even cured. The irradiation thus produces the same effects as vitamin D.

It was not easy for the physician to guess that these two agencies, so apparently unlike in their nature, and utterly unlike in the mode of administration, could produce the same effect on metabolism. While the clinicians of the past century were experimenting with cod liver oil, the presence or absence of sunlight was affecting their results without their knowledge, and thus causing confusion. The difficulty was aggravated by the facts that the particular rays which are effective are invisible, and that they do not pass through glass. A child who was given a sun bath in a glazed "sun room" was not thereby protected from rickets; but the child who was taken into the open air on a sunny day was protected. Hence the physician very naturally, though erroneously, attributed the curative effect to the fresh air. Jacobi,[6] in an article on rachitis published in 1885, related that more than twenty years previously he had been in occasional attendance upon a certain baby suffering from rickets and convulsions. No treatment produced any benefit until, without the physicians' advice, the father took the baby into the street in the hardest winter weather. After the first long outing the baby was well of his convulsions, and "the physicians profited by their involuntary experience." Jacobi attributed the cure to the fresh air, and the fresh air theory was held for a long time afterwards.

But while Dr. Jacobi was writing a summary of his observations in America, an English physician, Dr. Palm, was practicing in Japan, and he noticed in that country the absence of rickets among the children of the poor. This observation led him to make a study of the geographic distribution of rickets. He gathered a great mass of data from three continents, and from these data he drew the conclusion that the important factor in the distribution of rickets is not fresh air but sunlight. About thirty years later the fact that sunlight cures rickets was proved experimentally by Hess and Unger, of Columbia University.

In 1904 an attempt was made in Germany to cure rickets by means of electric light, but the attempt was not very successful, because the bulbs used were of glass, and the glass prevented the

[6] A. Jacobi, "Rachitis." Reprinted in Collectanea Jacobi, Vol. 3, Contributions to pediatrics. New York, 1909 (see p. 182).

emission of the ultra-violet rays. In 1919, in a home for rachitic children in Berlin, Dr. Huldschinsky cured some of the inmates in two months by irradiating them with a quartz mercury-vapor lamp, which emits ultra-violet rays in abundance. The quartz lamp is now coming into general use, as a means of curing rickets.

Ultra-violet rays have been proved to be of great practical importance in curing "weak leg" in growing chickens, a disease which, as was explained above, is similar to rickets. Ultra-violet rays were first used on chickens by J. S. Hughes at the Kansas Agricultural College. An extensive experiment has just been conducted in the Harvard Biophysics Laboratory under the direction of Dr. W. T. Bovie, and at the University of Maine under Dr. C. C. Little. A rickets-producing diet was fed to 225 chickens. It was found that the rickets can be prevented or cured by three different treatments. The first consists in mixing cod liver oil with the food. But the oil is evidently distasteful to the chickens; it causes them to eat less and to gain less weight; therefore it is not a practicable method for the poultryman. The second method is to give the chicks constant access to an outdoor run, where they enjoy the sunlight. But this is not always practicable in our northern states, where the spring weather is far too severe for little chicks. The third method is to expose the chicks 15 minutes daily to the rays from a quartz lamp. This method is probably a practicable one for the poultryman, at least as a supplement to natural sunlight.

Experiments on animals have been emphasized throughout our discussion, because they yield such definite results. The investigator can subject an animal completely to the conditions called for by the experiment. He can not do this with a baby. It would not be ethical to produce rickets deliberately in a baby for experimental purposes. In so far as this is true, our knowledge of the disease in babies must always remain less precise and less certain than our knowledge of it in animals. But immediately after the great war, Dr. Harriette Chick, of England, saw an opportunity to try some fairly definite experiments on babies. There were many babies in Vienna who were being fed on a rickets-producing diet, because they were under the care of a physician who had more faith in calories than in vitamins. Miss Chick secured permission to take some of those babies under her charge. She went to Vienna with a staff of physicians and assistants and with the necessary supplies. She proved that rickets can be cured in the human species, as it can in the rat and in the fowl, by cod liver oil or by exposure to sunlight or to the rays of a quartz lamp. In so doing,

she not only verified a theory, but also improved the health and probably saved the lives of some of the babies.

No one has yet determined precisely which rays are effective in curing rickets, but it is known that they are of wave length[7] shorter than 313 mμ, and perhaps even shorter than 302 mμ. Such radiation is entirely beyond the range of our vision. It can not pass through glass, and therefore can not enter our houses except when the windows are open Perhaps at some time in the future children's nurseries will be fitted with quartz window panes, which will allow the ultra-violet of the sunlight to enter. That will be a boon especially to prematurely born infants, who can not be taken out of doors. Ultra-violet radiation is absorbed to some degree by pure air, and much more by air laden with dust and moisture. Consequently, in the streets of a dark, smoky city there is very little of it. At sea level in bright, sunny weather there is enough of it to cure rickets if the patient is out in the sun for some hours each day. In high mountains there is more of this radiation; but even the mountain sunlight has passed through a hundred miles of air and has lost most of its ultra-violet rays during the passage. The light of a quartz mercury-vapor lamp is far richer than mountain sunlight, in ultra-violet; it is so rich that, as was mentioned in connection with the experiment on chickens, rickets can be cured by exposure to the quartz light for 15 minutes a day.

In this article we have aimed to give a summary of empirical facts regarding the prevention and cure of rickets, especially by vitamin D and by ultra-violet rays. We have not discussed the problem of explaining how these two agencies influence mineral metabolism and how they cure rickets. That problem will be treated by Dr Bovie in a subsequent article.

[7] The millimicron, mμ, is 0.000001 mm, or about $\frac{1}{25{,}000{,}000}$ inch.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

NEW FASHIONS IN LOCOMOTIVES

ONE curious thing is observable alike in the evolution of inventions and the evolution of plants and animals They will run along about the same for many years or centuries, getting bigger perhaps but retaining essentially the original structure, and looking much alike; and then all of a sudden new varieties will appear, many different kinds, and the primary form, forced to meet these new competitors, is either crowded out or undergoes a rapid development. The biologists call this multiplication of novel forms and freaks a "mutation" period.

The railroad locomotive is now in the midst of such a mutation period. For the past hundred years it has stuck strangely close to its original type. In looking over the models of locomotives in the National Museum last week I was struck with the monotony of the exhibits The "John Bull" that was built by George Stephen in 1831 for the Camden and Amboy R. R. looks about as much like the giant locomotive of to-day as a colt looks like a horse. It employed the same power and consisted essentially of the same parts: coal tender, furnace, boiler, piston engine, big wheels behind, little wheels in front, smokestack, headlight, cowcatcher and bell, all the familiar things arranged in the familiar order.

But now we are beginning to see various new varieties of locomotives; some without coal, some without pistons, some without steam, some without fuel of any kind. The electric locomotives fed with power through a third rail or trolley wire look more like the old steam engines than they need to, probably for fear of disconcerting the engineers and shocking the public. It is a wonder the makers do not think it necessary to stick on a fictitious smokestack with a pennant of black gauze streaming out of the top to satisfy our sense of the fitness of things.

In Europe steam turbines are being used in place of the old reciprocating engine. Leon Metais, a French engineer, has invented a locomotive in which the steam is first used in a high pressure turbine and from this passed on to a low pressure turbine. These run a dynamo which sends its current to eight motors, one on each axle. It is claimed that such an engine will run longer and get more than four times the power out of a given amount of fuel.

The Diesel engine, which does not employ coal or steam but gets its power from the explosive combustion of petroleum under high pressure, is still more efficient and economical. In Sweden the Atlas Company, of Stockholm, makes a locomotive with a Polar Diesel engine of the four cycle sort with twelve cylinders.

The Soviet government has had constructed at the Esslingen works in Germany a Diesel electric locomotive which claims an efficiency of 21 to 27.4 per cent. at a load of 440 to 1,060 horse-power, and a reduction of two thirds in the fuel consumption.

WILLIAM JAMES BEAL

In his botanical garden at Amherst, Mass., at the age of eighty-seven years. Dr. Beal was a pioneer in botany and professor at the Michigan Agricultural College for fifty years. The engraving is taken from the memorial prepared by Mr and Mrs Ray Stannard Baker, after the death of Professor Beal at the age of ninety-one years.

In America also efforts are being made to break away from the steam engine by using some form of the Diesel engine with electric drive and control. The General Electric Company has built a trial locomotive of this sort which is now being loaned out to various railroads willing to give it a trial in their switching yards. Its 300 horse-power engine is directly connected with a direct current generator of 200 kilowatts. The 60-ton locomotive carries with it enough fuel for 48 hours of continuous switching service. It consumes only .43 pounds of fuel oil per brake horse-power hour.

The Baldwin Locomotive Works expects to be running trains this summer with its new type of Diesel-electric locomotive which it has perfected after ten years of experimentation on the problem of construction. This is said to save between 25 and 50 per cent. in the cost of fuel over the steam engine. It uses a twelve cylinder two-cycle Diesel of more than a thousand horse-power.

If the steam engine is to meet such competition it must reform its ways and curtail its extravagance, and it is beginning to do so. The American Locomotive Works has built for the Delaware & Hudson Company R. R. a 273-ton engine that brings steam to a pressure of 350 pounds instead of the customary 200, and is said to be capable of developing a third more power with the consumption of a third less fuel and water. The new locomotive is appropriately named the "Horatio Allen" after the engineer who imported and ran for this company in 1829 the "Stourbridge Lion," the first locomotive to be set to work in America.

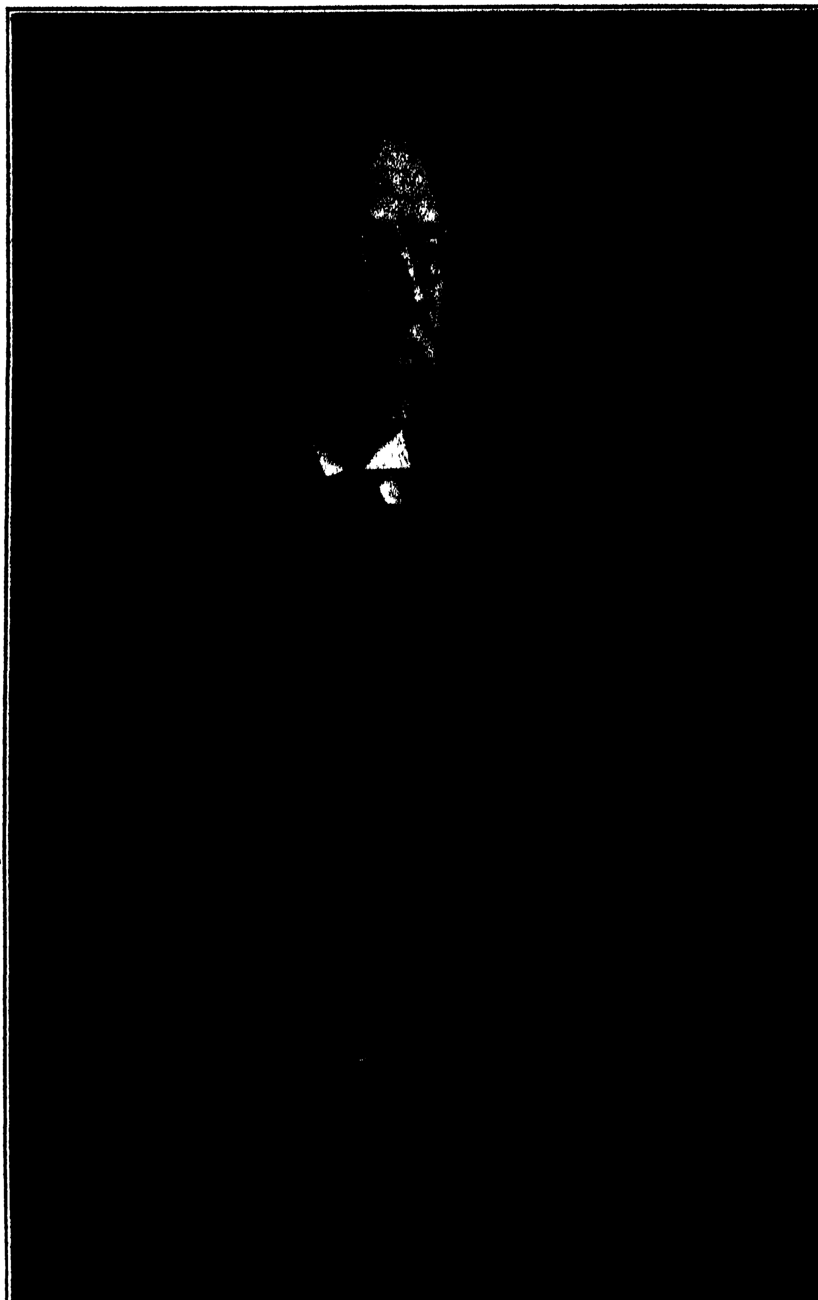
The old steam engine has lost its monopoly and it remains to be seen whether it will be crowded completely off the tracks or be content with a humbler position.

TWELVE YEARS' HUNT FOR A GERM-KILLER

Readers of the item appearing recently in the papers, that a new disinfectant had been discovered fifty times as strong as carbolic acid, had no way of knowing what lay behind it—or before it.

In the first place the word "discovered" is misleading. This conveys the impression of a lucky strike, like the diamond that a child in South Africa picked up as a pretty pebble or the nugget of gold that a sheep herder stumbled upon in Australia. Such is a true discovery, the accidental finding of something already existing. But this new germicide is not, properly speaking, a discovery; it is an invention, as much an invention as a new radio apparatus. It is not a natural product, suddenly found to be of value, like quinine in Peruvian bark. It is the successful culmination of a long, arduous and systematic study of how to construct a molecule that would serve a particular purpose; this particular purpose being to produce a chemical that would distinguish in the dark between the friends and foes of the human body, that would pass through the blood stream, killing all the disease germs it met and not injuring the body cells which are so much like them in size, shape and composition that the microscopist has difficulty in telling them apart.

The beginning of this research, the germ of the germicide, is to be found in a paper that Professor Treat B. Johnson, of Yale University, published in the *Journal* of the American Chemical Society in 1913. And he has stuck to it ever since until now, a dozen years after, his work is publicly recognized as one of the triumphs of modern medicine. The



—From the Book of Portraits of the Faculty of the Medical Department of the Johns Hopkins University, by Doris Ulmann

WILLIAM H. WELCH

Director of the School of Hygiene and Public Health, The Johns Hopkins University, distinguished for his contributions to pathology and medical education, who celebrated his seventy-fifth birthday on April 8.

"Yale Bulldog" spirit gains victories in other fields than football, although the papers do not make so much fuss over them.

The material for the new disinfectant comes from that same big black grab-bag from which the chemist has drawn so many useful dyes and drugs, the coal-tar barrel. One of these products, phenol or carbolic acid, is a valuable antiseptic, strong but clumsy, careless in discriminating between the invading microbes and the home guard. It sears the flesh like a hot iron when applied in full strength.

A near relative to phenol is resorcinol, a milder substance which some of us have used in the vain attempt to make two hairs grow on a head where none would grow before. Now both these compounds consist essentially of a ring of six carbon atoms, and what Professor Johnson discovered was a new way of attaching a chain of carbon atoms to this ring. This enabled him to make a series of similar compounds with side chains composed of from one to any number of carbon links, and it was found that the power to destroy germs increased as the chain was lengthened until there were six carbon atoms in the chain, but fell off thereafter. So the most powerful germicide of this series is the sixth which is accordingly called "hexyl-resorcinol," though doubtless a name with less than six syllables will be selected for it before it is put on the market, otherwise people would be reluctant to call for it at the drug store.

Professor Veader Leonard, of Johns Hopkins University, who has been testing the antiseptic power of these compounds, finds this compound is about fifty times as effective as our old carbolic acid. That is to say, it could be diluted with fifty times as much water and would still be as poisonous to the microbes without injuring the bodily tissues It can be safely taken internally by the mouth, and since it passes out largely through the kidneys it may be used to destroy the microbes and parasites of a tract of the body that has been hitherto difficult of access.

The member of the family with four carbon atoms in the side chain, known as "butyl-resorcinol," is about half as powerful, but may prove quite as useful for such purposes as gargles, tooth-paste and the treatment of skin wounds, for it is stable and has no disagreeable odor.

All these compounds and many others are being systematically prepared and their physiological effects investigated by a committee of the National Research Council. Such team work is likely to bring about much better results, quicker and more reliable than the haphazard efforts of isolated individuals. The ideal germicide is yet to be found, and it is quite possible that in time something may be found, or rather made, to take the place of such metallic poisons as mercury and arsenic, which do kill the parasites of the body but not without danger to their host. We also have reason to hope that the chemist may make something that will hunt out and destroy the bacillus of tuberculosis in its most secret lairs.

A PAINLESS WAY OF PAYING WAR DEBTS

WHEN a man finds himself overwhelmingly in debt and unable even to pay the interest, he naturally thinks of realizing on his real estate, especially if he owns more land than he can work. Why should not a nation do the same?

France, for instance. France is land poor. The country taken altogether is larger than the United States, fifty-four per cent. larger. France has extensive territories in Africa, Asia, America and Oceania which she

—From a photograph by Julian Scott

DR. W. J. V. OSTERHOUT

Professor of botany in Harvard University, who will become a member of the **Rockefeller Institute for Medical Research.**

has neither the men nor the money to develop. She has debts that she is too poor to pay.

Among her chief creditors is the United States and among her scattered parcels of property is one which is valueless to her but would be of great value to us, that is, French Guiana. This is about the size of Maine, mostly virgin territory, and largely unpopulated. Only about one twenty fifth of one per cent. of the area is under cultivation. It is rich in natural resources, mineral and agricultural, yet the French make no use of it except as a penal colony and are likely to abandon that. Few Frenchmen live there except the convicts and their keepers, so there would be no violation of local patriotic sentiment in its transfer to a foreign flag. If we should accept this territory in lieu of all France owes us we should be paying $156 an acre for it, an absurdly extravagant price, yet we could afford to make a very considerable reduction in our bill against France, for it would be better to have something tangible rather than rely upon promises already partially repudiated.

Great Britain alone among our debtors is paying up, yet she finds the burden of taxation almost intolerable and should be glad to be relieved of part of it by the cession to us of British Guiana. This is larger and richer than the French, yet is unprofitable to the mother country. It is larger than Utah, but less than two per cent. of it is occupied and less than a quarter of one per cent. is under cultivation. Only four per cent. of the scanty population is of European origin. We could not afford to cancel all that England owes us in exchange for British Guiana, for that would figure up about $70 per acre, yet we paid Denmark $500 an acre for the Virgin Islands.

That France and England could get relief from their heavy obligations by selling to the United States their surplus territory in and about the Caribbean Sea has been suggested by Professor Charles Gide, of the Paris Law Faculty, and by Lord Rothermere, brother of Lord Northcliffe. We should hesitate to take at any price the West India islands, for they have scant area and dense population, but the Guianas are the opposite and rather resemble the North American continent when we took possession of it. Under American administration and by means of American machinery the Guianas could be made a source of supply for petroleum, sugar, rice, rubber, beef, hides, lumber, hemp, cocoanut oil, cocoa, fruits and alcohol for motor fuel. This is almost the only undeveloped territory area of all the immense area lying between the Orinoco and the Amazon. Tropical real estate is bound to rise in the future on account of recent scientific discoveries and no country can afford to be without it. In a recent discussion of the problem of British Guiana at the Royal Society Professor L. Knowles said: "I have little doubt that the nation which controls the tropics will in the twentieth century control the most important raw materials and the growing markets of the world." France and England might well let us have this small fraction of the 2,300,000 square miles that they gained in the war which we aided them to win.

ELECTRIFYING THE SKIN

When sunlight strikes the bare skin it knocks out an electron from one of the atoms on the surface. This discovery was announced before the French Academy of Sciences on March 2 by Jean Saidman.

He stood a man on a stool insulated from the ground by legs of glass or rubber and gave him a certain charge of negative electricity, which of

course is altogether imperceptible to the person experimented upon. The electricity leaked away gradually and in 250 seconds three quarters of it had disappeared. Then he turned a ray of ultra-violet light from a mercury lamp twenty inches distant upon a section of the exposed skin less than two inches square and found that the electricity leaked away four times as fast. Three fourths of the original negative charge was gone in 64 seconds instead of 250. When a larger area of the skin was irradiated the loss of electricity was more rapid. Sunshine produced the same effect, though more slowly because the light of the sun is not rich in the energetic rays beyond the violet end of the spectrum. The leakage of electricity continues for some seconds after the light is shut off, probably being carried away by ionized particles of air and dust.

It has been known for some years that when a metallic surface, such as a polished plate of silver or copper or a fresh cut face of sodium or potassium, is exposed to ultra-violet rays it loses negative electricity. This is due to the detachment of the corpuscles of negative electricity, known as "electrons," which revolve in the outer orbits of an atom about the central and positive nucleus. This action of light on electricity is called the "photo-electric effect" It is this photo-electric effect that causes the photographic plate to record the image which the light casts upon it. It is this that activates the green leaf to store up food by aid of energy of the sun's rays.

The human skin is found to be one third as sensitive to the photo-electric effect as a sheet of copper, and we may find in this an explanation of the mystery of the curative effects of sunshine on the skin. The ultra-violet rays have a wave-length too short to be perceived as light by the eye, and they are unable to penetrate the clothing or the skin because they are so easily absorbed Even a microbe, so small as to be barely visible in a microscope, is too thick for these short waves to pass through. So if one microbe is lying on top of another when exposed to these rays the top one will be killed by them, while the lower one, being sheltered by the body of his mate, will escape injury.

Yet the ultra-violet rays of bright sunlight, or the stronger rays produced by the mercury quartz lamp, not only tan or burn the skin but have a profound effect upon the deeper tissues, changing the composition of the blood, stimulating it to greater activity against disease germs and often curing sores and bone diseases. This is to say, these short and easily deterred waves which can act only on the outer surface of the skin produce more profound effects upon the whole system than the longer waves of red light and heat which readily penetrate the skin and even pass through the entire body. M Saidman suggests that the influence of the ultra-violet rays is exerted through the photo-electric effect on the surface which is transmitted from layer to layer into the interior of the body.

The use of violet and ultra-violet and radium rays in this country is becoming a fad that seems likely to rival the famous blue-glass craze of the seventies. All sorts of ray apparatus and preparations are now finding a ready sale for the cure of all manner of ailments, but it may be said of most of them that they are either too weak to be of any use whatever or too strong to be used indiscriminately and unintelligently. It requires a specialist and expert to employ powerful rays of this kind, for they may produce very serious effects at the time or much later. Those who want to experiment for themselves in this fascinating field of radio-

therapy should stick to the oldest source of such rays, the sun. It will be cheaper for them and they will run a risk of nothing worse than a sunburn.

HOW TO LOSE WEIGHT

I HAVE learned how to lose weight without dieting, exercising, drugging or massaging. I have long been interested in this question, not only from scientific curiosity, but for personal reasons which it is not necessary to mention. Knowing that many others are interested for the same unspecified reasons, I hasten to give the information freely to the world.

I have not tried the process yet but I will not wait for that. If people with a new panacea for bodily or political ills delayed recommending it to others till they had tried it out the world would lose much literature. Besides I get the information from the weightiest authority on weight in the country, namely, the U. S. Coast and Geodetic Survey, which makes gravity determinations at over 300 stations with the utmost accuracy. The survey does not apply the results of its investigations to the personal problem. The credit for this is wholly mine. But from the survey figures I extract the following secret:

The way to lose weight is to travel.

But it all depends upon the way you travel

You must go from high latitudes to low latitudes or from low land to high land, or better, do both.

For instance, if you weigh two hundred pounds—I don't mean to insinuate that you do, but some people do, and it makes the figuring easier to start with—if you weigh two hundred pounds at the North Pole—of course you don't, but call it so for convenience—and you journey to the mouth of the Amazon, you would weigh only about 199 pounds there, and this is not considering possible losses on the voyage. This may not seem to everybody a considerable reduction, but if you weigh two hundred pounds you will know that it is well worth working for. Every merchant knows that marking down an article from $2.00 to $1.99 makes it much more attractive to bargain hunters.

If you travel from the North Pole to the top of Mount Chimborazo, Ecuador, which is near the equator and four miles high, you would reduce your weight from 200 pounds to 198.6. Of course, in order to gain this loss you would have to be weighed by spring balances and in a vacuum, for if beam balances were used the weight of the weights would fall off in the same proportion as you did and if you were weighed in air its buoyancy at low levels would tend to counteract the effect.

Or, if you are not interested in your personal avoirdupois, you could make money by buying gold on Mount Chimborazo and selling it at the North Pole. A nugget of gold weighing 200 ounces Troy on the mountain would increase in weight by about 1.4 ounces on being transported to the Pole and would be worth about $28 more. But perhaps it would be more profitable to travel about Europe and take advantage of the exchanges.

The reason for such variations of weight is due to the fact that a rotating body develops a centrifugal force that tends to throw off any loose object on its rim. We have all been struck by this while standing near an automobile speeding by in the mud.

Since the earth is a rotating body it, too, develops a centrifugal force which would be sufficient not only to throw off all unattached objects on

the surface but to tear the earth to pieces, like a giant defective fly-wheel, if it were not overbalanced by the centripetal pull of gravitation.

The pull of gravity, as we ordinarily understand it, is a combination of two pulls or forces, the gravitative force of the earth and its centrifugal force. Both of these forces vary for different places on the earth. The centrifugal force varies from a maximum at the equator to zero at the poles, due to the fact that the linear speed of rotation is greatest at the equator and nothing at the poles The other force, gravitation, depends upon the distance to the center of the earth and is, therefore, greatest at the poles, since the distance to the center is there 13 miles shorter than from a point on the equator. For the same reason gravitation is less at sea level than at the top of a high mountain peak in the same latitude.

There are other causes for the variation of gravity on the surface of the earth For instance, gravity is less on a plateau than at the top of a sharp mountain peak of the same elevation, and is less above rock of low density than above heavy rock. It is possible that the discovery of material of abnormal density by gravity observations may have some bearing on the search for mineral or oil deposits hidden deep in the earth.

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ECOLOGICAL CONDITIONS IN NATIONAL FORESTS AND IN NATIONAL PARKS

By Dr. CHARLES C. ADAMS

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INTRODUCTION

TWENTY years ago when our party was making ecological surveys of Isle Royal, Lake Superior, I became deeply impressed with the importance of the study of natural conditions. At that time there were relatively few who called themselves ecologists, students of the relation of organisms to their environment, and some of the most competent of these were primarily interested in the application of ecology to economic problems and were to a corresponding degree slightly interested in natural or wild conditions, largely because ecology seemed to them too remote or unimportant as far as their immediate needs were concerned. At that time they had not yet come to realize that one of the basal limiting factors which prevented the better application of ecology to their special subjects was on account of the relative neglect of this science, upon which their progress depended. The applications of ecology to industries and to public policies can naturally progress no faster than the basal science upon which they depend. This is as true of the applications of ecology to our national parks and national forests as of other economic and social problems. The arts of agriculture, forestry, fisheries, medicine and public health are all dependent, to a very important degree, upon advances in our knowledge of the relation of plants and animals to man and also man's relation to his own species.

To-day not only has the number of workers increased, but in addition there has been a greatly improved appreciation of the

FIG 1. Overgrazed and overbrowsed Gambel oak, browsed up about six feet, one fourth mile east of old Grand View Hotel, Grand Canyon National Park, south rim of Canyon, Arizona. About one half mile from water.

value of studying wild, unmodified nature, not only for the value of its scientific results, but as well because of the assistance which such studies give in solving practical problems. In recent years there has been a growing recognition of the practical value of wild areas among foresters. The older champions of our national parks, as John Muir, were among the leaders in this country to see in a broad way the value of preserving wild areas, but in recent years there has been an intensive movement to get vast crowds of people into the national parks, and at such a rate that vast areas of the parks are without question being severely injured. The encroachments of agriculture and forestry upon wild lands are also rapidly transforming them from wild areas. Agriculture seems to have practically overlooked the value of preserving wild areas for any contribution which their study can make to this art, although of course for recreational purposes the farmers have eagerly availed themselves of wild areas.

In recent years ecologists and foresters have come to a much better mutual understanding, better in many respects, it seems to me, than between themselves and the students of agriculture. The relation of ecology to forestry has, in the past, been mainly on the

FIG. 2. Overgrazed and overbrowsed cliff rose (*Cowania*), injured and killed, about one half mile east of old Grand View Hotel, Grand Canyon National Park, south rim of Canyon Scattered lupine in foreground, pinyon and yellow pine in background.

plant or forest side, but more recently the animal aspect of the subject has come in for a clearer recognition, particularly with regard to the influence of grazing animals, and with regard to wild life, and last but not least to the educational and recreational aspect of the subject The mutual relation existing between ecology as a science and its applications has thus been increased, is much better understood, and we are now coming to see that if we are to preserve in any adequate manner the national parks for future generations there must be applied to them a knowledge of ecology. The relation also of ecology to the forests is progressively receiving greater recognition.

With regard to national forests, as contrasted with national parks, the great bulk of their area is intended to be modified from a wild state to increase their value to man, primarily from the economic standpoint. Here the cutting of timber, the grazing of the forage and the utilization of wild life and the conservation of water and soil are the avowed purpose of these forests. Wild land within such forests, excepting protective forests, will thus be the exception rather than the rule. The vast areas of the forests,

FIG. 3. Overgrazed and overbrowsed Gambel oak, area unprotected by pasture fence, and relatively protected area within pasture, near old Grand View Hotel, Grand Canyon National Park, south rim of Canyon.

with their extensive methods of management or cultivation, give a vast area for ecological study, the ecology of managed forests will be a perennial field for ecological study, and it will furnish one of the most attractive professions for the ecologist.

During the past summer and early fall I made a tour through a number of national forests and national parks. The localities examined were mainly in New Mexico, Arizona, California and Utah, during which special attention was given to the ecological conditions, and to noting the relation which forest and park policies have had upon these I have tried to look at conditions impartially, and some of the findings I will now discuss. As I have been teaching and investigating animal ecology and its applications to both forests and parks for several years my views have been influenced by certain general considerations, as I view these as phases of the general land problem. I went over the areas rather carefully, took careful notes and photographs, and was generally accompanied by some one familiar with the region and well informed in general on local conditions. I will confine my remarks largely to regions examined during the past season (1924), although

FIG. 4. Overgrazed meadow, with cattle, Sand Meadow, South Fork of the Kaweah River, Sequoia National Park, California.

my observations have not been limited to the regions mentioned. I alone am responsible for the opinions here expressed

The American idea of a national park is to set aside a region of supreme scenic features as a true sanctuary or haven where plants and animals should be preserved in as near primeval conditions as is humanly possible in this modern world. Such an ideal is a high one and will cost much effort to maintain. It will perhaps require almost as much effort to protect the parks from their superficial unthinking and ignorant friends as from their commercializing enemies and the cheap politicians, who are looking out for their own personal advantage. The national park idea is one of the few valuable American contributions to a policy of land use. It should be conceived in a broad comprehensive manner. At times there has been undue emphasis upon the minor and trivial recreational uses, and not enough attention has been given to the use of the word in its better sense, or "higher use," because without question the educational and scientific and esthetic value of these parks is of supreme importance. As I see it, our national parks are devoted primarily to social uses, recreation, education and science. On the other hand, the national forests have, in the past, been devoted to economic utilization, from the standpoint of timber production, grazing, watershed protection and water power. In recent years, however, the public has invaded the national forests for recreation, and has thus become interested in the forests as never before,

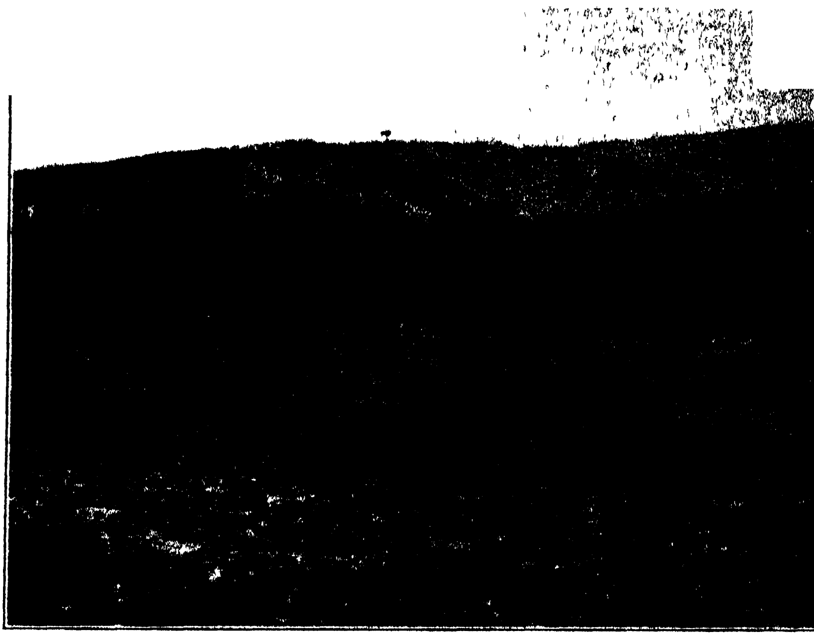

FIG 5 Overgrazed meadow, Mitchell Meadow, South Fork of the Kaweah River, Sequoia National Park. Near the location of area shown in Fig. 4.

both state and federal, and has forced the national forests rather reluctantly to recognize their interest as one of the major uses of forest land. The tradition and ideal of foresters has been so strongly economic that this social demand has been recognized mainly on account of strong public pressure, rather than by the use of foresight which is generally used in making forest working plans Certain individuals have, however, grasped this conception very fully One of the next important practical problems is how to balance properly the economic and the social influences. This the public will decide for itself and we hope under capable leadership. Without question there will be in time a tendency to break down the distinction between parks and forests, but without question the rank and file of the two groups are still so far apart, and it is perhaps well that they are for the present, as both groups have something of importance to learn from each other, before they can work together to the best advantage for public benefit.

I will discuss, first, national park conditions and follow this by considering the ecological conditions in the national forests.

Ecological Conditions in National Parks

Preliminary remarks: During the 50 years in which we have had national parks there has been a growing appreciation of the

FIG. 6. Protected meadow, showing thriving herbaceous vegetation, near head of Dead Man's Creek, Sequoia National Park.

American idea of preserving for our own and for future generations some of the outstanding wonders, scenic, plant and animal, which our country possesses in unusual abundance It is remarkable that during all this time there has been no adequate recognition of the fact that these wild parks call for a new profession, far removed indeed from that of the training needed for the formal city park or that of the conventional training of the forester, with a basal knowledge of plant and animal ecology which should be combined with certain arts and methods of administration and an adequate economic and social background. On the other hand, in a much shorter period, forestry has become a profession. The first national forests were created about the Yellowstone National Park, in order to protect it, and now the forests have vastly outgrown the parks in acreage, in organization and in administration.

First of all, we should recognize that the National Parks Service, as a unified organization, was only established in 1916, although the Forest Service was similarly organized in 1905. The founding of the Yale Forest School (1900) was a major influence in professionalizing men for the Forest Service. Several other teaching organizations have since developed so that the forests are now securing the benefit of mature and experienced men, whether or

not they were trained in the schools or worked up through the ranks. There has, however, been no corresponding development of an adequate training for the national parks. The Forest Service has always been in charge of a forester, but the parks have never been headed by a similar technical man.

To interpret fairly the conditions in the parks one must bear in mind this contrast between the administration of parks and the forests The parks are, in administration, only newly organized and are not yet free of all trace of their former military tradition. They are relatively poor because, excepting automobile licenses, they have no large revenue comparable to the grazing and timber sales of the national forests, and Congress has not yet learned, or the general public for that matter, that in order to administer properly these wonderlands calls for a staff of men—well-trained technical men The park officials are not yet completely under civil service, and are without a professional tradition behind them, although it should be recognized that this is not always an advantage. We lack therefore in the parks mature and formulated knowledge and policies of park administration.

The Forest Service was for many years overloaded with administrative duties, to such a degree that research was sadly neglected, and during that interval certain errors were made, which might have been less serious if there had been research to guide The Park Service is now in the same relative position, and even as important as is the position of the park naturalist and the nature guide service, these men are not definitely devoted to technical research, but in the main to elementary educational work with the park visitors Not all the parks have naturalists, and a considerable amount of their energies is given to publicity. Publicity is of course valuable, but such duties may not allow sufficient time for serious scientific studies. Furthermore, under the present system there has not yet been time to make adequate physical and natural history surveys of their domain, detailed and photographic records of the status and condition of their areas. A considerable body of data of this character must be accumulated, digested and formulated, before each particular park can have satisfactory working plans or policies, such as modern administrative methods require, and such as are found in most of the national forests. If we are to understand the ecological conditions in the parks we must bear these considerations in mind.

These administrative policies of the parks form a large part of the human influence upon them, and are to-day dominating influences affecting the ecological conditions within the parks. Let

us turn to certain conditions worthy of special attention in the Grand Canyon, the Sequoia and in the Yosemite National Parks.

Conditions in the Grand Canyon National Park: The Grand Canyon National Park in Arizona was formerly included within a national forest; it was later made a national monument and finally in 1919 it was made a national park. It is thus a new park and has not yet had time, and with several different superintendents, to settle down to a stable policy based upon a detailed knowledge of the situation. (In passing we should note that the oldest park of all, the Yellowstone, has not yet developed and published its system of management.) The ecological conditions were already greatly modified from a natural wild park when it became a national park. It was considered necessary, in order to get the park established, to permit grazing by local residents who owned some private land within the park. These same persons grazed in the adjacent Tusayan National Forest. The overgrazed condition of the region of the south rim of the Grand Canyon is thus, particularly near the watering places, in exceedingly bad condition, as Figures 1, 2 and 3 show This excessive overgrazing has made the south rim country of the canyon as severely overgrazed, primarily by domestic animals, as is the north rim in the Grand Canyon Game Preserve, with its excessive number of deer and domestic animals, combined. This is a deplorable condition, which influences the wild life, changes the character of the vegetation, favors the erosion of the soil and produces conditions directly the opposite of the intention of a national park.

As a rule also where grazing animals are allowed there is a more aggressive control of predatory animals, and yet no one has ever made a satisfactory scientific study of this problem in any national park, or for that matter in any national forest, and published the results. As a result of this unsatisfactory condition, and independently of predatory control measures, the rangers in some of the national parks have been permitted, I have been informed on good authority, to trap fur-bearing animals to supplement their meager salaries.

The situation with regard to fishing in the Grand Canyon National Park is representative of conditions in other parks. Thus, the annual report of Superintendent W. H. Peters for the year 1920 states on page 312 that "Bright Angel Creek has been stocked during the year with eastern brook trout."

At the Toronto meeting of the Ecological Society of America, on December 28, 1921, it passed the following resolutions:

Whereas one of the primary duties of the National Park Service is to pass on to future generations, unimpaired, the wilderness of the parks, including their native plants and animals; and

Whereas there are many educational and scientific reasons why the native plants and animals should remain unmixed through importations of other organisms not native to the parks; therefore be it

Resolved, That the introduction of non-native plants and animals in our National Parks be *strictly forbidden* by the park authorities, it being expressly intended that the planting of non-native trees, shrubs, and other plants, as well as the stocking of waters with fish not native to the region, is strongly opposed. Be it also

Resolved, that copies of these resolutions be sent to Hon. Stephen T. Mather, Director of the National Park Service, to Mr. Horace M. Albright, Field Assistant to the Director, and to Mr. Robert Sterling Yard, Executive Secretary of the National Parks Association. (*Ecology,* Vol. 3, pp. 170–171, 1922.)

Dr A O. Weese, secretary-treasurer of the society, sent a copy of this to Superintendent Horace M. Albright, field assistant to Director S. T. Mather, to which he replied under date of January 23, 1922, as follows:

My dear Mr. Weese:

I have received copy of the Resolutions of the Ecological Society of America on the native flora and fauna of the National Parks adopted at the recent meeting of the Society in Toronto. I want to say that the present policy of the National Park Service is directly in harmony with this resolution. In Yellowstone Park we do not permit the importation of exotic plants or animals, and we are adverse to the planting of any species of fish not native to the Yellowstone region. In the past exotic fish have been planted in the Yellowstone to the detriment of its waters as fishing streams, but this practice was discontinued some years ago. We are strongly in favor of planting nothing but native or cutthroat trout in most of the waters of the park and confining our plantings of grayling and rainbow and eastern brook trout to streams that have already had these species in them.

I am glad to say also that in my capacity as Field Assistant to the Director I have noticed in my travels among the other national parks that everywhere the superintendents are carefully adhering to the policy of the Park Service that foreign plant and animal life are not to be brought in.

It is a pleasure to know that the Ecological Society is taking such a keen interest in our national parks.

Cordially yours,

HORACE M. ALBRIGHT,
Superintendent.

From the above it is seen that the continued stocking of waters, by exotic species of fish, after they had once been planted, is regularly practiced in the Yellowstone, and by consulting the last annual report of the director it will be seen that this is also done in many other parks. These exotic species, planted by error, should

not be maintained in the parks at all, but should be reduced in every way possible, and no replanting of these species should be permitted. The planting of exotic fish in the Grand Canyon is mentioned merely as an example of a general policy which applies, as has been said, to many of the national parks.

[illegible]rk officials are certainly to be commended in their efforts t[illegible] the wild burros which live in the Grand Canyon. They [illegible] to the park and utilize forage needed for the native [illegible]

[illegible] is no park naturalist in this park, so that there is no competent man on the staff to study these problems and accumulate data, [illegible]m the authorities and to keep the public informed as t[illegible] natural history conditions in this park.

[illegible] in the proposed Roosevelt-Sequoia region: The S[illegible] National Park in Southern California is a high mountain [illegible] of great beauty, and is the region in which the giant trees [illegible] reach their ecological optimum It is, therefore, the [illegible] which the preservation of these forests can probably be [illegible] most successful, and this feature should be made a paramount feature in this park These trees and their ecological associates form a unique resource which is certainly of national park quality, and nothing should be done which will obscure this feature. The administration of the park should never lose sight of this. In fact, the care and appreciation shown these trees is an excellent criterion by means of which the efficiency of the park service may be judged.

The summer administrative headquarters are located in the Giant Forest, in the finest and largest of all the sequoia groves, and as a consequence of this concentration of traffic, much of the herbaceous vegetation and young trees, which escaped the grazing animals, have been trampled down and destroyed Cattle and horses have also destroyed much of the low vegetation in the nearby meadows. Of what use are regulations against picking flowers when cattle may eat them? The local officials to some degree appreciate this situation, but they must have public support to remedy it. On the other hand, the local officials have strongly advocated "light burning" of the forest floor, as a means of getting rid of the inflammable litter, including the old fallen trees and stumps.[2] Fires have been a permanent feature of the region, and their complete exclusion will probably in time completely change the appearance of the forest, and probably no one yet knows enough, and has the financial backing necessary, to practice light burning suc-

[2] *Cf.* Ann. Rep. Director Nat. Park Service for 1924, p. 110.

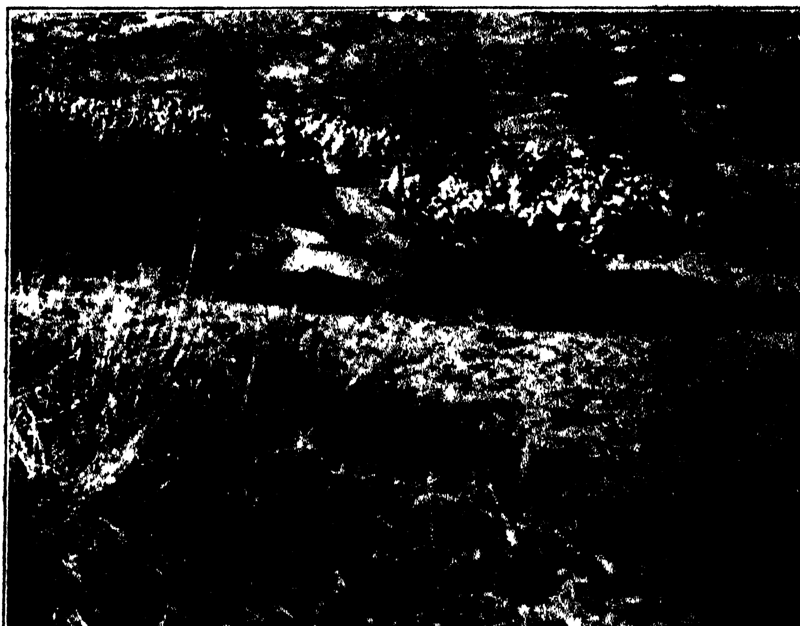

FIG. 7. Protected summer range of deer. Eight deer were seen on this slope at the time the photograph was taken. In the area which it is proposed to remove from the Park and put into a Game Preserve, Upper Soda Creek basin, Sequoia National Park.

cessfully in such a manner as to maintain "virgin forest conditions"! To pass on unimpaired to future generations the park forests is indeed no simple undertaking. In the past there has been some reason for confusion on this subject, but now the results of many years of careful study are available,[3] showing clearly that not only do such fires not really reduce the fire hazard but in fact increase it, that fire favors certain kinds of forests and brush, and thus selects and changes the character of the vegetation, and finally that it really costs more to execute such burnings than it does to give adequate fire protection. To burn over every few years the 161,600 acres of the Sequoia Park and the 719,800 acres of the Yosemite at the cost of from .30 to $1.00 per acre for a total of nearly 900,000 acres would be a very expensive operation. Suppose only 500,000 acres were "light burned" at a cost of $250,000. The last annual appropriations for the two parks totaled only $445,000. To secure such an increase for fire protection alone even over a period of years would be a very serious undertaking, particularly in the face of other acute needs. On the other hand, the fire exclu-

[3] Show and Kotok, U. S. Dept. Agr., Bull. No. 1294, 1924.

FIG. 8. Severely overgrazed meadow, Cahoon Meadow, near the Giant Forest, in Sequoia National Park. Compare with Figs. 6 and 7.

sion methods of the Forest Service cost per year about one and a half to three cents per acre Thus from every standpoint "light burning" should not be practiced in our national parks.

In this connection attention should be called to the clearing up of the débris produced during road construction, which too often disfigures the highways in the national parks. Some of the débris, as the soil and rock, should be disposed of when the roads are being built, the timber should be salvaged and the brush and stumps should be burned This plan, however, has not in the past been followed out so that to-day there remains considerable cleaning up to be done, and this is a decided improvement, as has been shown by Superintendent Horace M Albright.[4] But this sort of cleaning up should not be confused with the burning of natural dead and down timber and other forest litter in these parks. Every field naturalist knows that to remove the dead and down timber would at the same time destroy the necessary breeding sites and cover for many animals.[5]

[4] *American Forests and Forest Life*, Vol. 31, pp. 36–37, 1925.

[5] *Cf.* Grinnell and Storer, 1924, "Animal Life in the Yosemite." Berkeley.

FIG 9. Giant trees below this gap in Dennison Ridge, on the Tule River slope, showing character of the Sequoias which it is proposed to remove from the Sequoia National Park and place in a Game Preserve. Photograph by courtesy of Ernest G. Dudley.

When the Sequoia Park was made in 1890, grazing was soon stopped but was again permitted in 1917 and continues to this day. The overgrazed condition was quite evident in the two southern townships (Figs. 4 and 5), and it was only in the extreme eastern high part, in the vicinity of Wet Meadows, where the grasslands did not show severe overgrazing, as shown in Figs. 6 and 7. Conditions in the northeastern township, from the Giant Forest to the Mt. Silliman region, suffered more possibly than any other overgrazed area I observed within a park or a forest. The condition of the Cahoon Meadows, shown in Figs. 8 and 11, is a good sample of the overgrazed condition of these meadows, but along the trails the tramping of horses and cattle have done immense damage that will probably require 25 years or more for recovery, and we do not know that even then there will be a true recovery to natural conditions

The summer and winter range of the deer is a problem of considerable importance. Migratory animals, such as deer and elk, have been the source of considerable friction between the Park Service, the Forest Service and with several of the states. It is well, therefore, to plan to avoid this difficulty rather than to en-

FIG. 10. View from the gap in Dennison Ridge, on the Tule River slope, looking out upon the region with the large grove of Giant trees which it is proposed to remove from the Park. Tops of the Sequoias in the foreground. Sequoia National Park.

courage it by adopting new policies which fail to eliminate this factor. The present Sequoia Park includes some excellent summer range for deer. The best which I saw, and where deer were most abundant, was in the extreme southeastern township of the park (T. 18 S. 31 E.) in the vicinity of Wet Meadows, as shown in Figs 7 and 11. During one day in that township our field party saw 34 deer and passed through magnificent red fir forests.

It is proposed, in the present Barbour bill (H. R. 4095), now before Congress, to cut out of the park about half of this township, a most important part of this summer range, with the large sequoia grove south of Dennison Ridge in the Tule River drainage, and add to this a narrow strip of forest about Mineral King and make a game preserve of this in the Sequoia National Forest. The occasion for extending a game preserve in the heart of a national park is not evident, and the mines are definitely known not to be of importance. This preserve idea if carried out is certainly destined in the future to make friction. The natural overflow of deer from the park into the forest will be available for hunting without the creation of such a preserve. Furthermore, I see no satisfactory reason for taking out of the present park the large sequoia grove

south of Dennison Ridge on the Tule River slope. This area has, in about 600 acres, as estimated by Mr. Ernest G. [illegible] and Mr. H T. Britten, of Exeter, California, "at least 50[illegible] over ten feet in diameter." This stand Mr. Dudley states is [illegible] body for its size (nearest pure stand) of sequoias in [illegible]" This is the opinion of a forester who assisted his uncle, [illegible] W. R. Dudley, of Stanford University, in making ext[illegible] studies of these trees and who later made a detailed study o[illegible] for the Forest Service. Mr. Britten, formerly a park r[illegible] knows the region thoroughly, has patrolled it and assures [illegible] accessibility from the Garfield Grove. Without questio[illegible] is of national park quality, as indicated by the trees [illegible] Fig. 9. It is now in a national park where in my opinion i[illegible] remain, and it should not be removed in order to create a[illegible] reserve. If these trees are taken from the park, they sho[illegible] protected specifically by law or made a national monument wi[illegible] national forest. Standing in the gap of Dennison Ridge an[illegible] south, many of these trees screen the view, as shown in [illegible] Such considerations as these mentioned show that, both [illegible] of the deer and the sequoias, these areas should be included within the proposed Roosevelt-Sequoia Park. The accompanying maps indicate the proposed boundary changes, Fig. 11, including a proposed approximate southern boundary line as well as an important addition north of the present park, near Mount Silliman, which is needed to consolidate the park, and to provide for overcrowding, which is already doing the parks great injury. These changes are approved by some of the best informed local

Neither in the Sequoia Park or in the proposed park is found the native haunt of the beautiful golden trout named for Roosevelt[6] This Roosevelt trout deserves more than a passing notice. Evermann has said:

> This is the most beautiful of all the trouts; the brilliancy and richness of its coloration is not equaled in any other known species; the delicate golden olive of the head, back and upper part of the side, the clear golden yellow along and below the lateral line, and the marvelously rich cadmium of the under parts fully entitle this species to be known above all others as the golden trout. In form it is no less beautiful; its lines are perfect, the fins large and well proportioned, and the caudal peduncle strong; all fitting it admirably for life in the turbulent waters in which it dwells. It is a small fish, however. . . . The golden trout is native to Volcano Creek alone, and occurs throughout the entire length of that stream. . . . As a game fish the golden trout is one of the best. It will rise to any kind of lure, including the artificial fly, and at any time of day. . . . It is a fish

[6] *Cf.*, Evermann, U. S. Bur. Fisheries, Vol. 25, pp. 1–51, 1906; Evermann and Bryant, Calif. Fish and Game, Vol. 5, pp. 105–135, 1919.

that does not give up soon but continues the fight. Its unusual breadth of fins and strength of caudal peduncle, together with the turbulent water in which it dwells, enable it to make a fight equaling that offered by many a larger trout. . . . Although now abundant the golden trout can not long remain so unless afforded some protection. The attractiveness of the Kern River region because of its scenic beauty is sure to appeal more and more to tourists every year. Practically the entire length of Volcano Creek is easily accessible from the trail from Kern River to Mount Whitney, and that portion above the tunnel is covered by the trail from the east side of the divide. As a matter of fact one can in one day travel the entire length of the creek and have time to stop frequently to drop a fly into the pools which he passes. The trout are readily found and are easily captured, as they are so voracious and rise to the lure so readily Two years ago the members of the Sierra Club and others accompanying them on their annual outing to Mount Whitney are said to have taken 600 or 700 trout from Volcano Creek in one day. . . . As already stated, it is only a question of time, a very few years at most, when the golden trout of Volcano Creek will become practically exterminated unless it receives some protection.

Evermann and Bryant in conclusion say:

This, the most beautiful trout in all the world, was named in honor of Theodore Roosevelt, the naturalist, who, as President of the United States, ordered the investigation which resulted in its discovery as a new species.

The preservation of the Roosevelt trout in the Kern River drainage, east of the present Sequoia Park, and southeast of its proposed enlargement (in area No. 2, of Fig. 11) is thus wholly in harmony with the true interests of our national parks and the park boundaries should therefore be changed to include the native haunts of this trout in Golden Trout or Volcano Creek. In the Sequoia National Forest, where they are now located, they are under the control of the state of California. If this proposed park is to bear Roosevelt's name why should the waters including the Roosevelt trout be excluded and why should any of the park and adjacent forest waters containing these and allied fish be stocked with exotic kinds, not native to the park, thus risking the loss of their beautiful native species which live nowhere else in the world? Why destroy the unique features to produce the commonplace? I raise this question of exotic fish because the Loch Leven trout were planted, while I was there this summer, in the waters of the Sequoia Park. This is not in harmony with the ideal of maintaining the unique features of the park unimpaired.

In brief, with regard to the Barbour bill (H. R. 4095) now before Congress, it should be *amended* as follows:

(1) The region including Golden Trout or Volcano Creek, the native haunts of the Roosevelt trout, should be included within the proposed park by adding Region No. 1, of Fig. 11.

(2) The proposed game preserve should be abandoned, leaving undisturbed the summer range of the deer and the big grove of sequoias on the Tule River slope (south of Dennison Ridge) within the park.

(3) The large re-entrant angle north of the present park should be greatly reduced by adding to the proposed park Area No. 2, of Fig 11.

But this problem of exotic or non-native species is not confined to fish, for I am informed that some years ago an effort was made to stock this park with Chinese pheasants. An effort was made, some years ago also, to stock the park with wild turkeys. Thus Supervisor Walter Fry's annual report of 1916, on page 50, informs us that:

> Wild turkeys are fairly abundant in the Sequoia Park in the vicinity of the junction of the Middle Fork and Marble Fork of the Kaweah Rivers, and there is every indication of their having become firmly established. Of the three different types that were placed in the park during the seasons of 1909–10, *viz.*, Mexican gray, Arizona bronze and Texas black, the two former species seem to have entirely disappeared This fact is attributed to their either having died, been caught by predatory wild animals, or blended to such extent as to form intergradation to the latter mentioned species. It would seem, however, the latter to be the most feasible of the three causes given. The turkeys range in two separate groups; one that ranges at the mouth of the Marble Fork is quite tame like most other birds of the parks, but the other has a higher altitudinal range several miles in extent and are so wary it is difficult to ever see them.

These experiences with exotics raise a question. Does the public wish to travel hundreds of miles to visit the unique regions of California to be greeted with Chinese pheasants, Loch Leven trout and Arizona, Texas or Mexican wild turkeys, and in all probability at the expense of the native animal species? Clearly this subject is serious enough to deserve more attention than it is receiving. I believe that most of the park officials will readily respond to suggestions from naturalists and the public, but we see how such matters have drifted and are now drifting without adequate supervision.

Conditions in the Yosemite National Park: The Yosemite is one of the best known and most frequented of our national parks. In certain respects this park has had a very progressive history and in other ways its history has been rather discouraging. The Hetch Hetchy Valley episode is a good example of the sinister influences which invade the parks. The state of California deserves great credit for turning over its large area of state land to the federal government for this park. If California would now purchase all the private lands within the park and turn these over to the park, it would be an excellent piece of public work, because without ques-

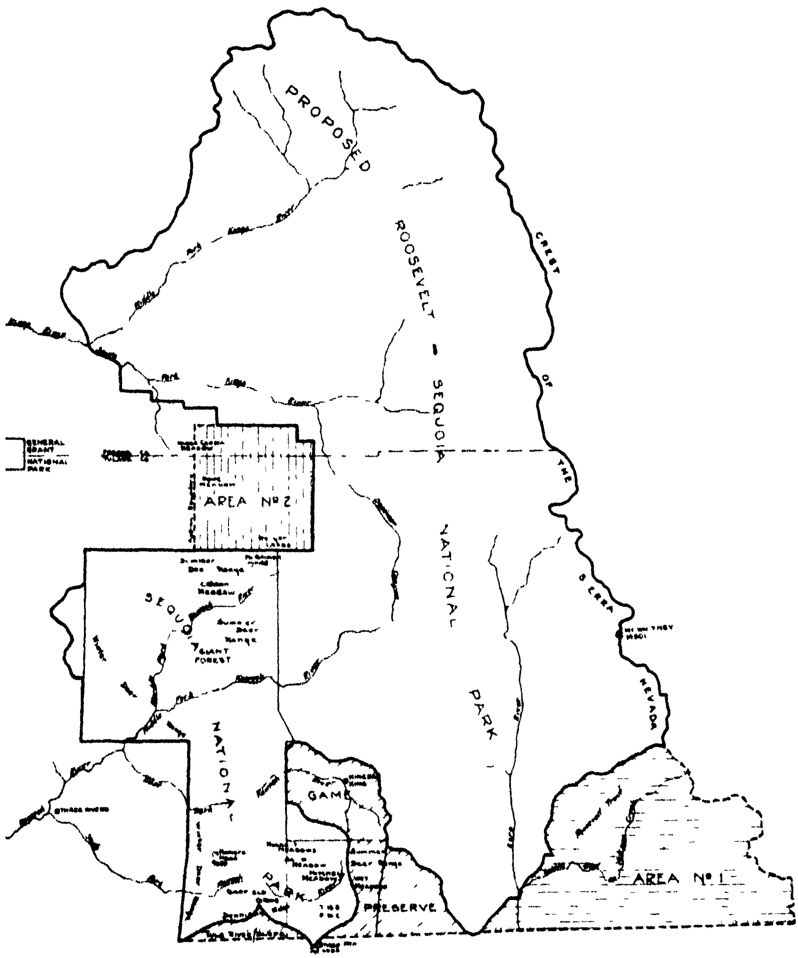

FIG. 11. Map of the proposed Roosevelt Sequoia National Park region. Showing boundaries of Sequoia National Park, the areas which the present Barbour bill (H. R. 4095) proposes to cut out of the proposed Park, and the boundaries of the proposed Game Preserve The areas which should be added to the Park are Nos. 1, 2 and the proposed Game Preserve areas.

tion this is one of the greatest menaces to this park to-day. The general public does not seem to be aware of the seriousness of the situation. There are to-day over 10,000 acres of privately owned lands within the park, and over 10,000 have been acquired by the Park Service. But in order to salvage the land along the highway, park timber has been sacrificed. The local officials have had to deal with a very serious problem and have evidently made heroic efforts to make the best of a very bad situation. Lacking funds and authority to prevent the cutting on private lands within the park,

FIG. 12. Mule deer in Yosemite National Park. Photograph used by courtesy of Mr J. T. Boysen, Yosemite.

their only alternative seemed to be to trade for land along the road, giving more remote and less conspicuous lands, which in themselves surely should never have been cut.

Sooner or later the American public should be fully informed about these private lands within the various national parks, and funds should be provided to condemn and buy all such lands. Furthermore, we are probably drifting toward the position of forbidding the cutting of timber in any of the national parks. Most of these parks are adjacent to national forests and it is from these that all needed timber could be secured. If the forests in these parks should be kept forever wild cutting can not be harmonized with the wilderness condition. Possibly the only solution of these problems is for the Park Service to adopt a policy of intensive improvement of the parks they already have, including the purchase of all private lands within their boundaries, and to delay expansion until the present parks are safe and adequately cared for.

The development of a scientific and educational staff has made unusual progress in the Yosemite. The nature guide service has developed rapidly here, and now with a gift of money from the Laura Spelman Rockefeller Memorial for a museum, there is an

FIG. 13. Mother black bear and three cubs in Yosemite National Park. Photograph used by the courtesy of Mr. A. C. Pillsbury, Yosemite.

unusual opportunity afforded to establish, at least in one national park, an adequate resident scientific and educational staff within a park. The parks are truly in desperate need of such guidance, such as can only be secured from a truly capable technical staff living and working there the year round.

Yet in spite of all this local interest in the welfare of the park, the floor of the Yosemite Valley, as a piece of wild nature, is largely annihilated, and the introduction of exotic Loch Leven trout continues, although the present restrictions on pasturing the meadows will assist in allowing a partial recovery of the wild flowers. Mention should also be made of the introduction of plants by Dr. Harvey M. Hall, of the Carnegie Institution, as a part of his studies in experimental plant ecology. No doubt as long as they are under his supervision they are likely to cause no trouble, but when the experiments are terminated a special effort should be made to see that all the extraneous plants are removed as they should not be allowed to add exotics to the native flora. The eastern opossum, which has invaded Sequoia Park, and is not a native, should be killed off with the excess of predatory animals.

Deer (Fig. 12) abound in the park in summer, but very few indeed remain within it during the winter. At any time this part time seasonal control of the deer may become a serious menace. The presence nearby of the foot and mouth disease in cattle, during the past summer (1924), spread to the deer in adjacent forests, and on the winter range there is an excellent chance to infest the

FIG. 14. Park visitors feeding bears in the Yosemite. A dangerous practice. Photograph used by courtesy of Mr. A. C. Pillsbury.

park deer. This risk alone is a sufficient cause for forbidding all grazing in our national parks. The situation with regard to the bear appears to be more satisfactory. The bears, as elsewhere in the national parks, are very popular with the public (Figs. 13 and 14).

Ecological Conditions in the National Forests

Preliminary remarks: As has been indicated the aims and ideals of the national forests are to-day primarily economic, with a rather rapidly increasing recent recognition of the direct social value of wild life and recreation. These differences are reflected in their management policies, particularly in relation to the vegetation and animals of the forests The trees are considered primarily from the standpoint of timber production, watershed protection or the retardation of erosion, the shrubs largely from the standpoint of shelter, watershed protection and erosion, and as browse for domestic grazing animals and deer, and the herbaceous growth from the standpoint of forage and as a retarding influence on erosion. The larger predatory animals, birds or mammals are looked upon largely as a menace to the grazers or game, to a limited degree as game, and the minor mammals, such as rodents, as competitors for forage or browse. Timber and watershed protection were the older ideals of forestry, but with the inclusion of the open forests and grazing land, wild life and recreation have been reluctantly added,

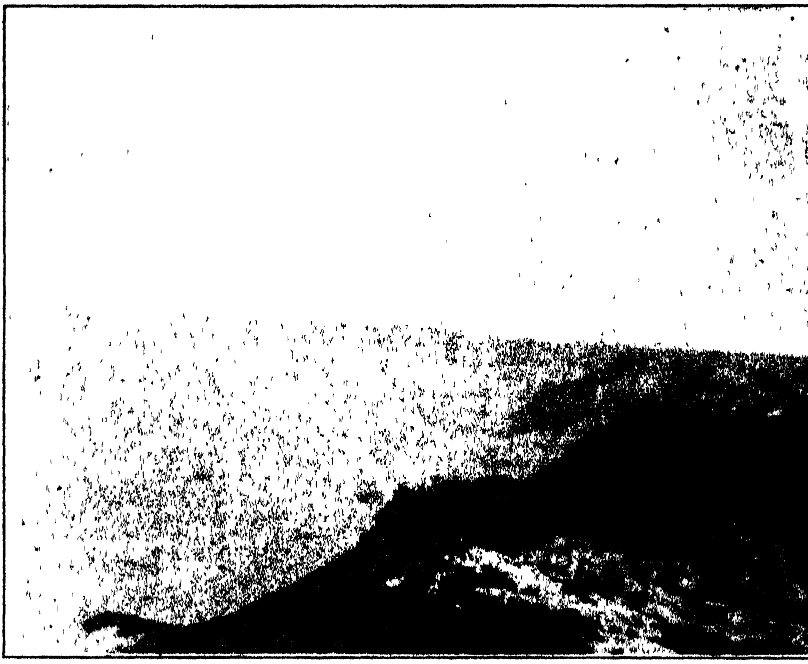

FIG. 15. A side canyon of the Grand Canyon, the western rim of Kanab Creek Canyon, which forms a natural barrier to the extension of the Kaibab mule deer on their winter feeding grounds. Kaibab National Forest, Arizona.

as the regional policy of land use, rather than a tree crop policy solely, has been gaining recognition. There are also healthy signs of recovery from the effort to utilize exotic trees and game, but none yet for exotic fish. The injury and confusion caused by this method of mixing the native and exotic plants and animals have gone on without much regard to the well-known ill effects caused by such mixtures. The results of the introduction of rabbits into Australia, the mongoose into the West Indies, the English sparrow, carp and gypsy moth into America, ought to serve as a warning, with the mere mention of the blister rust of white pine and the chestnut blight. In spite of the fact that we have wonderful native species suited to many purposes there are many persons who are continually, in the face of considerations just mentioned, neglecting the native species and seeking to encourage exotic ones.

It is evident from these considerations that the whole policy of the forests has been in the past to modify the ecological conditions as much as is possible to conform to the extensive use of certain biological resources of the regions, from the standpoint of timber, forage and, more recently, wild life and recreation. To this degree

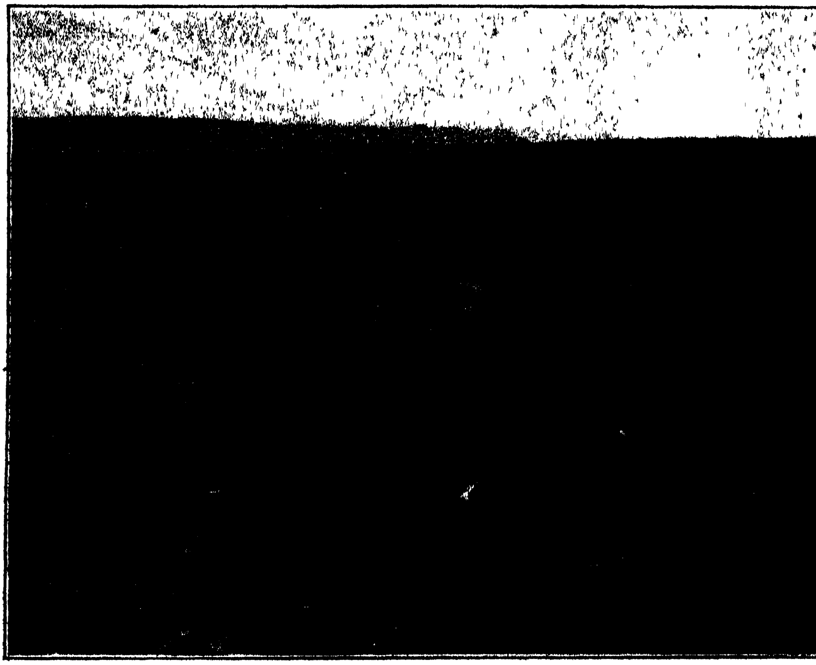

FIG. 16 The sage brush desert, between Fredonia, Arizona, and the northwestern corner of the Kaibab National Forest and the Grand Canyon Game Preserve. The Kaibab plateau in the background. This desert is heavily grazed by sheep during the winter and is largely Public Domain.

there has been a marked contrast between the theoretical park policy of the wilderness, to which in practice as we have seen, the parks have not adhered, and that of the forests. The policies of the forests are worked out in considerable detail and are based on surveys of almost all degrees of intensity with regard to the timber, to a less degree the forage, and still less so to wild life. Recreational camping has been worked out in great detail in certain areas of the west by the men on the ground who have to deal with these matters, but the results of their studies have not been made public in any adequate fashion.

The Forest Service has always been active in methods of fire control and this has, of course, a powerful influence upon both plants and animals. They have not, however, secured complete control over lumbering methods and brush disposal and until this is done an important preventable cause of fires is not under control. Of course private lands adjacent and within the forests are often a severe fire menace.

The widespread overgrazing seen in the national forests influences the general ecological conditions as a dominating influence.

Not only are the herbs, shrubs and trees influenced directly but as well animals dependent on them. Another condition is greatly modifying natural conditions and that is the practice of the service in its extensive cooperative fish cultural work with the U. S. Bureau of Fisheries and with the states to stock public waters with fish not native to the region.

We see that the ecological conditions in forests are thus undergoing profound changes from wild and primeval conditions and there are almost no parts remaining of these areas which will remain wild, unless a new and definite policy[7] is developed of holding as reserves certain areas. There are, however, many reasons for maintaining such areas for scientific study, demonstration and education and for recreational uses, although this idea has not yet received much recognition in forestry.

The interests of ecologists are not by any means confined to wild areas, or their subjects would be on the decline rather than on the increase. We must recognize, however, conditions as they exist.

Conditions in the Tusayan National Forest: In an arid region the injury caused by fire is very pronounced because aridity makes fire-fighting very difficult, and because the relatively slow rate of plant growth leads to slow recovery. The arid yellow pine and pinyon-juniper forests are so open that they produce forage and browse, and grazing is carried on in them extensively. The limited number and amount of watering places tends to concentrate grazing about such localities, and this results in extensive overgrazing. The use of both the forage, browse and water for stock to a corresponding degree restricts its use for wild life. Thus the control of water at the same time controls much of the adjacent land available for wild life range.

In the Tusayan Forest, on the south side of the Grand Canyon, the dominating ecological condition, now of greatest importance, is the extreme overgrazing, similar to that on the adjacent national park. The condition of the range in the forest and the park are equally bad, so that you can not tell by the appearance of the range whether you are in the park or in the forest. This overgrazing is changing not only the herbaceous vegetation but as well the growth of young trees and brush of all kinds. The brush, such as Gambel oak and cliff rose (*Cowania*), is ridden down by stock and eaten and broken so severely that many of them die. This overgrazing not only injures the normal carrying capacity of the range, but also the reproduction of the trees, and the normal carrying capacity for deer and antelope. It is therefore to be condemned on every score.

[7] *Cf.* Ashe, *Jour. Forestry,* Vol. 20, pp. 276–283, 1922; Pearson, *Ecology,* Vol. 3, pp. 284–287; Leopold, *Jour. Forestry,* Vol. 19, pp. 718–721, 1921.

Predatory and rodent control are carried on by the Biological Survey in cooperation with the state of Arizona. Both of these influences are of course closely related to the range problem. The intensive over-grazing makes the competition with rodents relatively more pronounced and conspicuous and emphasizes the need of comprehensive policies which will balance all these influences.

Conditions in the Kaibab National Forest: On account of the remoteness and inaccessibility of the Kaibab Forest and the Grand Canyon Game Preserve one might expect to find it one of the finest wildernesses and untouched areas in the United States. Bounded as this region is ecologically by the park and Grand Canyon on the south and on the adjacent parts on the east and west (Fig. 15) by side canyons, and around its northerly edge by wonderful extensive deserts (Fig. 16), its position is quite unique on account of this physical isolation. The forests and meadows (Fig. 17) are wonderfully beautiful, and the surrounding country is equally interesting This would have made an ideal place for a true wilderness preserve. Not ideal, to be sure, for everything that every one might wish to have in a preserve, but certainly an ideal example of a wild area, and one in which there might be some hope of preserving a number of large predatory animals, such as the cougar, as well as deer, as Emerson Hough had hoped. But this forest having been set aside originally as a game preserve where grazing was wanted at the same time, predatory animals have been systematically killed and the stock and deer have been preserved. There was of course provision for utilizing the natural increase of the stock, but the federal game preserve contained no adequate specific provision for taking care of the normal increase of the deer (Fig. 18). The boundaries of the forest and park were changed, but the game preserve has not been enlarged. Naturally a period of stress was not far ahead. The overgrazing, particularly upon the winter range by an overpopulation of deer and by stock (Figs. 19 and 20), has continued, and only within the last couple of years has a serious effort been made to remedy the situation. The overcrowded condition on the summer range (Fig. 7), has been retarded in part by reducing the number of domestic animals. The preserve was formed by Congress in 1906, six years before Arizona became a state and therefore some basis exists for the claim that the state has never had authority over the deer. The Forest Service, which has had charge of the preserve, has been reluctant to grasp this bramble and crush its thorns so that a new situation arose about the deer which renewed the conflict between the Park Service and the Forest Service over this migratory game. For a number of

years I have been convinced that the wild life of the national forests should be under the full control of the Forest Service, as is the case of wild life in many of the national parks, in order that the Service might possess unified control over the forest, and include game management in its proper place within a comprehensive system of forest management. In the case of the Kaibab deer this was such an opportunity, but the Forest Service did not grasp this opportunity, study the situation fully and publish the results of its findings and its plans for management. This opportunity was allowed to slip by, and Emerson Hough, not being satisfied with the wild life management of either the Forest Service or the Park Service, suggested a new and independent plan, which was doubtless a cause of its failure.

Personally I have no choice as to which federal bureau has charge of this area; my only concern is that it be managed properly. I believe, however, that the best use to which the region could be put would be to maintain it as a wilderness and to keep the "improvements"—hotels, auto roads and their like—out of the region. From the standpoint of "highest use," for the welfare of the whole nation, this region could not, it seems to me, be put to better use. Either the Forest Service or the Park Service could care for this area, but their duties should be clearly prescribed by the law; otherwise there will be pressure from those who wish to exploit it for economic purposes.

Development of Park and Forest Policies

Preliminary remarks: The need of public policies for both the parks and the forests is a subject which should be almost self-evident, and yet we have not practiced this thoroughly, so that any one can without considerable effort learn the status of these policies. The Forest Service has published considerable information on certain aspects of this subject and there are books which deal rather fully with historical and legal aspects of it,[8] but we have no corresponding volumes of the parks, although Cameron's[9] volume is a partial substitute for this. Without question the lack of funds for publication has been an influential factor. It seems, however, that a fuller public statement, including even the provisional policies, of at least the more important forests, would be worth the effort. The larger the organization the more difficult it becomes to keep the individual members informed of the status of conditions, and the publication of these policies would help the service itself, as

[8] Ise, 1920, "The U. S. Forest Policy."

[9] 1922, "The National Park Service."

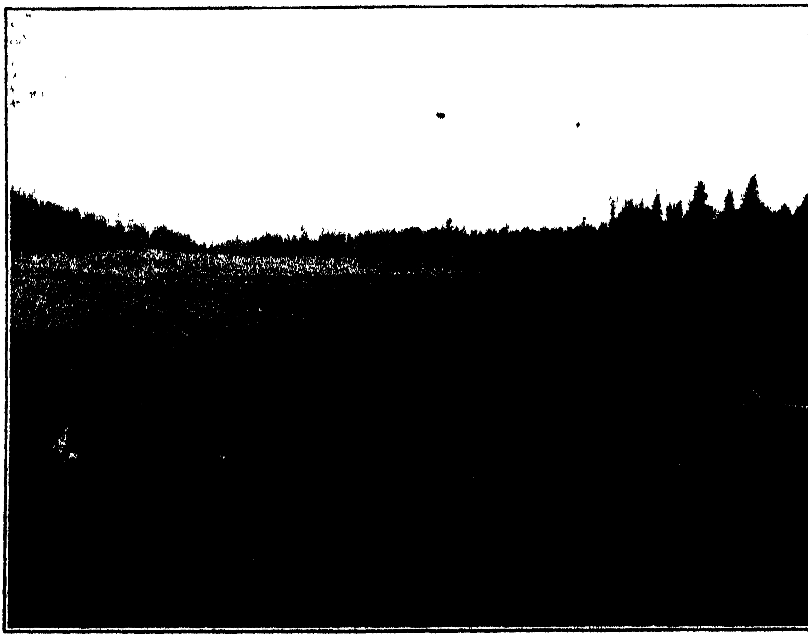

FIG. 17. Park-like meadow in the Kaibab National Forest, south of V T Park, showing the character of the summer feeding grounds of mule deer. Overgrazed by stock and deer. Arizona.

well as its relation to the public. To state the rules of the game and the conditions under which they operate should be salutary in many respects, and help to build up and maintain public confidence. Of course, there will be some disadvantages in following such a policy, but it hardly seems probable that they would overbalance the benefits.

Development of policies from within: I am considering policies as *formulated procedure* which have resulted from an effort on the part of the officials or organization to adjust their relations to the public. It is a response to the conditions, and involves contributions from the officials, or from within the service, and from the public, that is, from those without. Of course, in practice, it is often difficult to tell the origin of a given stimulus, whether from within or without.

The beginnings of our forestry ideas were, like most of our institutions, adapted from European theory and practice, and by degrees they are becoming adapted to our own conditions and institutions Thus our silviculture tended to be European, but our grazing methods are distinctly American, and the development of our wild life policies and recreation will surely be along American rather than European lines.

FIG. 18. Kaibab mule deer on the summer range, Kaibab National Forest, showing the absence of young aspens caused mainly by overbrowsing by deer and stock. Photograph by courtesy of Mr Albert Wilkes, Salt Lake City.

There are certain improvements in both the parks and the forests which can be best made from within, and there are others which are most likely to come from without. It is fortunate indeed that the forest service started with a distinct professional leadership and this was possible because European forestry was highly developed. But the idea of wild or wilderness national parks is a distinctly American idea and did not have a European tradition. The European tradition is about formal park design rather than large wild parks, such as our national parks. For this reason we must develop our own policies for the parks, as is being done for grazing and wild life in the national forests The recreational aspects of both the parks and the forests is largely a new problem in American life, and must be worked out by both the parks and the Forest Service.

I wish to emphasize that the recreational problem of the parks and forests will surely fall far below its best achievement if it does not strive to serve the "highest use" rather than to cater to the common urban amusement resort standard of recreation. We should thus bear in mind that the parks are not set aside solely for recreation, in the limited sense, but are intended for broad public benefit, including education and science. It seems to me that we are fully justified in expecting a very large contribution from within the Forest Service to the cause of recreation and wild life, primarily because this service has long been accustomed to making basal sur-

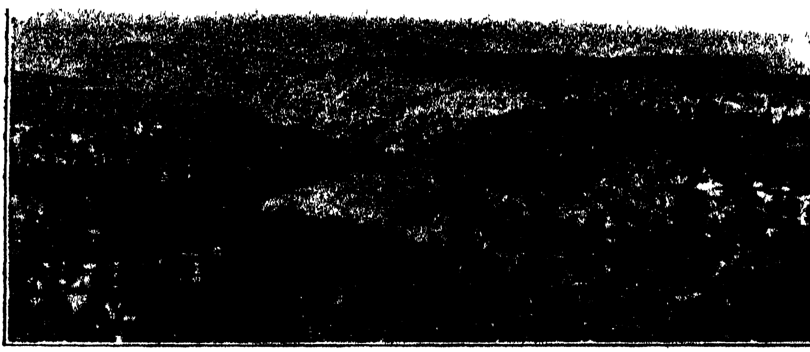

FIG 19. A general view of the western part of the fall and winter range of the Kaibab deer, looking toward Kanab Creek Canyon. Kaibab National Forest, Arizona.

veys of the resources, has formulated its method of recording and reporting data, and has for years been accustomed to formulating policies of management upon a long time basis. *I believe that this is the greatest contribution of forestry to our American institutions.* Any interested person who will spend time in the office examining the data on hand or by talking with the officials who deal with timber, grazing, wild life and recreation and who will examine carefully the wealth of data, maps and plans already made for the utilization of these resources, will be convinced of their ability to make a very important positive contribution to these aspects of forestry Field studies furthermore in the forest will I believe confirm this opinion. Several of these are developments which have come largely from within and, as developed in the west, in response to the public demand. The legitimate public demand for wild life and recreation, particularly in the east and mid-west, is so much greater than our national parks can ever expect to provide that in order to preserve the parks it will be necessary to develop, on a very large scale, the resources and facilities in the national forests.

As has been said on the other hand, the park service is new. It

Fig. 20 A detailed view of the western part of the winter range of the deer, showing the overbrowsed cliff rose (*Cowania*) in the foreground, and severely browsed junipers in the background, Kaibab National Forest and Grand Canyon Game Preserve, Arizona.

has during previous administrations not developed to an equal degree a tradition of formulated surveys, working plans and policies and is more nearly to-day in the position of wild life, and recreation, in the Forest Service. The Park Service has had to begin nearer the bottom and develop its own policies, handicapped by the lack of a certain amount of professional tradition. The result has been a relatively slower rate of development. The Forest Service has had, however, to pay its price for its professional advantage, as this has tended towards a dominance of economic ideals and sentiments, and consequently it has been rather slow in recognizing the full value of social ideals and sentiments. This explains in part some of its inertia in recognizing grazing, wild life and recreation as a part of their problem of working toward a policy involving the highest use of the land. It has even obscured the recognition that this principle of "highest use" is ultimately and essentially social. Even to-day in its research and publications the Forest Service has not shown adequate recognition of this aspect of its field.

It is difficult to generalize in such matters. But every one who has worked in any kind of organization knows something of the difficulties of improving conditions from within. One would prefer to think that improvements were mainly made from within, and yet only too often an outsider can accomplish in a relatively short time what one from within could not do in five, ten or fifteen years of excellent work The larger an organization the more difficult it is for the higher officials to keep in touch with the men on the ground who are in direct contact with conditions In my own field work, made in various parts of the country, I have come to have great respect for the opinions of the men on the ground. Often such men are without technical training and may make serious errors in many ways, but when it comes down to fundamental facts of observation and simple interpretation they deserve very careful consideration. The neglect of this on the part of officials, no matter from what cause, to avail themselves of this sort of information is the source of a vast amount of confusion. These men on the ground deserve more recognition than is generally given them

Development of policies from without: Having called attention to what may be called the internal factors, let us turn to some of the external influences which affect policies. Of course the supreme dominating external factor is the fact that we have had a new country with a public domain, out of which parks and forests could be carved, and new problems have arisen demanding solution as population increased and as the country developed. It is these pioneer conditions that forced the development of grazing upon the national forests and is now doing the same with wild life and recreation In the case of the parks the great immediate stimulus was the closure of Europe during and after the war to travel, and the diversion of these people to our western national forests, national parks and into Canada. Without question the automobile is a large factor in this situation, and a general movement of the people toward outdoor recreation that has developed with the industrialization and urbanization of our population. These are dominating economic and social conditions which are to-day making up the complex ecological environment of our plants and animals in our parks and forests.

As has been said, the Park Service and the Forest Service each have an important contribution to make toward this problem. The Park Service may well listen in addition to the demands of the transportation and concessionary companies, to many diverse social, educational and scientific organizations who have a true interest in the welfare and the development of park policies. The For

Service has also similar obligations not to give too much attention to the economic demands of local lumbermen, stockmen, power and irrigation interests, and to overlook national social welfare. These matters should be weighed carefully with a long look ahead, remembering that social values are difficult to weigh and that it has not been the habit of foresters or their training in the past to evaluate these considerations. It therefore suggests that careful provision should be made for errors. The old criterion of the "highest use" is of supreme importance, and foresters should recognize the "highest" means ultimately social rather than economic values Both the forests and the parks need to formulate their ideas and criterions of value so that when occasion arises they can dispassionately estimate relative values, or they will not to a corresponding degree hold firmly public confidence.

We meet with public officials who are fair-minded and who welcome an opportunity to explain and improve their policies. At the same time others look upon any suggestion or criticism as a political attack, possibly because too many of their critics have been politicians, or because they consider all criticisms a personal matter, and act as if they and not the public owned the forests and parks, and this of course only causes confusion and more trouble, and is not the successful method of solving problems.

Summary and Conclusions

I have brought these matters before the Ecological Society because I feel that they are vitally concerned with the ecological welfare of these millions of acres of federal park and forest land. From the standpoint of the naturalist these parks and forests contain a vast number of important and interesting scientific and educational problems. To solve these problems involves no new technique for those ecologists who have been accustomed to study the physical environment, the vegetation and the animals, including man, from a dynamic or process point of view. More attention, however, is needed to integrate these dynamic conceptions intimately with current economic, social and political problems.

There is no group of the public which should have a keener appreciation of the value of these regions and a keener desire to see that they are managed to the best advantage. As citizens they should be as much interested as any others, and as naturalists they have another additional interest. There are, then, special reasons why they should take on additional responsibility and assume a self-appointed guardianship looking toward the best management of these areas, and cooperating with other agencies having similar interests.

RADIO TALKS ON SCIENCE[1]

HOW SCIENTIFIC DISCOVERIES ARE MADE

By Professor ERNEST MERRITT
CORNELL UNIVERSITY

I FEAR that the title of this talk may be somewhat misleading—may even hold out false hopes. It sounds as though I intended to explain all the trade secrets of the scientist, so that every one who has the good fortune to listen in will be prepared to make his own scientific discoveries. If the newest dancing steps can be taught by a correspondence school, why not teach the art of scientific discovery by radio? In fact, to bear out the title "How scientific discoveries are made" I ought really to make one or two discoveries myself, just by way of illustration, while the radio audience "stands by."

Nothing quite so ambitious as this is intended, however. All I shall attempt to do is to point out the way in which some of the great scientific discoveries have been made in the past, with the idea that it will probably be under somewhat similar circumstances that great discoveries are made in the future.

For many years progress in all branches of science has been extremely rapid. We have come to take this as a matter of course. If at least one or two great discoveries were not announced each year we should feel that something was wrong and that the scientific machine ought to be speeded up. Some kinds of scientific work *can* be speeded up—for example, measurements or routine observations, and these may be of great value. But *discoveries* are different. No one can make a discovery to order. From the very nature of the case a discovery involves something that is unexpected, and the greater the discovery the more unexpected it is. If you discover something that you know is there it is no discovery.

There is a great deal of similarity between progress in science and the exploration of an unknown country. If an explorer starts out to discover some particular thing, like an oil well or a big water fall or the highest mountain in the world, he is likely to be disappointed. But if he starts out with the intention of simply going as far as he can into the unknown region and finding out

[1] Broadcast from Station WCAP, Washington, D. C., under the auspices of the National Research Council and the direction of Mr. W. E. Tisdale.

what is there, he is pretty certain sooner or later to find something of interest or value. If it isn't an oil well it may be a gold mine. If it isn't a water-fall it may be an equally beautiful lake.

The great thing is for the explorer to keep his eyes open and his mind alert so as to recognize the worthwhile new thing when he sees it. Open-mindedness and alertness are the great qualifications. Even if he has started out to find some particular thing he must be ready to change his plans if circumstances require it. Columbus started out to find a new route to India—and failed. But he discovered America instead. There are many cases like this in the history of scientific discovery. Take, for example, the discovery of radioactivity by Becquerel, which was the result of a combination of plausible but false reasoning and fortunate accident. Becquerel started out from the fact that X-rays had been found to come from those parts of a Crookes's tube which were being bombarded by the cathode rays and which were in consequence brilliantly fluorescent. The fluorescence of the glass was thought to be tied up in some way with the production of X-rays. Now Becquerel knew that certain uranium compounds could be made to fluoresce in sunlight even more brightly than in a Crookes's tube. So it seemed to him likely that X-rays could be produced simply by exposing these uranium compounds to sunlight. He tried the experiment by wrapping a photographic plate in black paper so as to protect it from light, sprinkling some uranium nitrate on the black paper, and then placing the plate in the sun for several hours. When the plate was developed the parts underneath the uranium compound were found to be blackened. Apparently Becquerel's reasoning was correct, and X-rays, capable of passing through the black paper, had really been produced. To make sure he prepared to repeat the experiment. A fresh plate was wrapped in black paper, uranium nitrate was sprinkled over the outside, and he was about to place the plate in the sun, when a storm came up. So he put the plate with its uranium nitrate in a dark closet and went to work at something else. Paris sometimes has pretty dismal weather, and this time it was several days before the sun appeared again. When the sun finally did appear Becquerel thought it was hardly safe to use the same plate—it might have been spoiled in some way through standing. So he prepared a new one. But just for fun he developed the plate that had been standing in the dark. And to his great surprise he found that it was blackened even more than the one that had been put in the sun! As a matter of fact, we now know that the sunlight and the fluorescence of the uranium nitrate had nothing

to do with it. Becquerel's original reasoning was entirely wrong. His results were due to the fact that rays similar to X-rays, but different, were being given out by the uranium all the time. He followed up the lead which this accident had given him, investigated the properties of these new rays, and suggested to Madame Curie the experiments which led to the discovery of radium and gave to us the best means yet known of combatting cancer. The whole subject of radioactivity started from this accident. But it did so because Becquerel had the mental alertness to take advantage of the accident. Many of us would have thrown the fogged plate away and thought nothing of it. Like Columbus, Becquerel failed in what he started out to do. But, like Columbus, he was more successful in his failure than if he had succeeded.

The discovery of X-rays by Roentgen is another illustration of the important part that accident plays in scientific discovery. Roentgen was repeating some interesting experiments that had been made by another physicist with a special form of Crookes's tube. He was working in a dark room, and on the table near his tube all sorts of things were lying around such as a physicist is apt to have in his laboratory. Possibly if Roentgen had been more neat and had kept everything in the right place he would not have made the discovery. Among the things near the tube was a small piece of a certain compound of platinum, and Roentgen noticed that this gave off a faint light every time he operated the Crookes's tube. It would have been easy to fail to notice this dim light or to dismiss it as of no importance. But Roentgen *did* notice it and recognized that he had to do with something new and important. In consequence the X-ray is now available for the surgeon, the dentist and the physician and has contributed to scientific progress in a dozen different fields.

Roentgen's discovery could not have been made except by accident, for the existence of such things as X-rays was not even suspected. This is true with most really great discoveries. It is the business of the scientific man to keep always in mind the fact that such altogether unexpected things exist in nature. In the words of Hamlet, "There are more things in heaven and earth than are dreamed of in our philosophy."

I sometimes tell my students of the experience we had in the Cornell laboratory immediately after the discovery of X-rays was announced. Like every one else we were much excited by the announcement and anxious to repeat the experiments. Among the apparatus in the laboratory we found an old Crookes's tube. We operated the tube, placed a photographic plate near it and got a

picture of the bones of the hand, which still hangs on the wall of my office. Now that old tube had been in the laboratory for twenty years. I had seen it when I was a freshman. Every year it had been shown to classes and operated—and each time it had given off X-rays. For twenty years our laboratory—and every physics laboratory in the world for that matter—had been in a position to discover X-rays. But we didn't. I wonder how many equally important phenomena are going on around us all the time waiting for a Roentgen or a Becquerel to discover them!

Another illustration of this sort of thing might be given from the field of radio broadcasting. The air is full of radio waves from stations all over the country. With your apparatus you can tune them in or out at will. If my talk verges too much on the highbrow you have only to turn a dial, and symphony or jazz will take its place. But suppose you had no receiving set; suppose you had never heard of broadcasting. The radio waves would be there just the same, all ready to add to your enjoyment of life if you could only learn that they exist and invent a receiving set by which to hear them.

I *might* use this opportunity to point a moral—but I think it is time for my radio audience to turn the dial and tune in on something else.

THE AGE OF THE EARTH

By FRANK L. HESS

Early man probably thought little of the age of the earth on which he lived; like a child he merely accepted it, and if he thought of the matter at all, the world was so enormous compared with his own puny size that it must always have seemed without beginning or end, for he saw no signs of either. In his experience anything made, such as a bow, a house or a wall, was made from something else equally visible, equally tangible and obtained from a known source. But the earth was too over powering. He guessed at its limits because everything else he knew, except time, had its limits. Even the sky came down only to the horizon, but when he traveled across the earth he always saw sea or land beyond. To him there was no end.

New ideas usually arise from a class that has leisure to sit down and think, and the existence of such a class means a fairly high state of civilization. Perhaps the priests of the ancient religions were the first to have this leisure, and they were also among the

ablest men of their nations. It is said that the Chaldean priests left observations of the stars dating back six thousand years and that they claimed to have observations running back four hundred and seventy thousand years, to a date at which they placed the creation of man in a world which, according to their reckoning, had already existed 2,150,000 years. This statement of the world's age was, of course, pure invention, as was that of Zoroaster, who is thought to have lived about one thousand years before Christ and who placed the age of the earth at seven thousand years.

In 1650 Bishop Usher published a chronology of the Bible, in which he paid no attention to the imagery of the East, in the language of which Moses wrote, nor to the indefinite time often indicated by the word "day," so that he counted the six days of creation as six periods of twenty-four hours, with the result that he placed the beginning of the world at 4,004 B. C., probably the shortest estimate yet made. His figures have been utterly disproved, but they are still printed in the margin at the beginning of some Bibles.

Unfortunately, many have treated the estimate of the really learned bishop as an integral part of the Bible, and the development of the science of geology has disturbed them greatly, because they felt that any deductions concerning the earth's history that were not in accordance with his chronology and with a narrow interpretation of Genesis were a direct blow at religion.

But there were many evidences of a vastly greater age than could be compressed into six thousand years. For instance, shells were found in hard rocks and they were so like living organisms that it could hardly be doubted that they too had once been the protecting houses in which snails, oysters, clams and other animals lived and died, though they must have existed a tremendously long time ago. This idea was attacked as irreligious. It was said that these fossil forms were the work of the devil or imitations made by the Creator. However, shells could be traced back by easy steps from those alive in the water to those dead on the beach, buried in the sands, encased in partly hardened sands or muds, and on down through the solid rocks.

Leonardo da Vinci, the artist-scientist, who was a contemporary of Christopher Columbus, recognized that the fossil shells had been living forms. By the middle of the eighteenth century an orderly succession of the shells was determined. To-day fossil shells are constantly used for telling the comparative age of the rocks, though they do not tell us the age in years.

Many other things show us that the earth is old. We watch a tiny stream of water run down a dirt slope. In a few days, or per-

haps even in a few hours, it has cut a considerable trench, but to cut through rocks takes immensely longer. However, we see the same sort of a cut made through the rocks and on a larger scale by a small creek, by a larger creek and by a river, and then we comprehend that even the stupendous canyon of the Colorado, which Dr. George R. Mansfield discussed before the radio audience last summer, was formed in the same manner. Obviously, the time required to cut such a chasm and to carry the waste down to the sea is not to be measured in days or centuries but in millions of years.

How slowly valleys may be cut is shown by the huge redwood trees of the Sierra Nevada in California. These trees grow along the slopes bordering small streams, and some of them show by their rings of annual growth that they are six thousand years old, an age that takes them back to the time when good Bishop Usher thought the earth was "without form and void"; yet the valleys have changed but little in these thousands of years, else the trees must have had the earth washed away from their roots and they would have toppled over and died.

Old as these trees are, they present only a part of the testimony that the redwood family can give us concerning the age of the earth. At Florissant, Colorado, there are stumps of trees eight or ten feet in diameter, long since turned to stone, that also were redwoods, possibly of a type that was ancestral to those of our day. These trees died and were petrified before the great-great-grandfathers of the California trees had sprouted, yet the Florissant trees also must have reached an age of several thousand years. A nearby volcano threw out great quantities of ash that killed and covered the trees, a lake was formed over them, and during the course of the ages the wood of the trees, bit by bit, was changed to flinty stone. Other falls of ash came, covering and preserving many species of leaves and myriads of insects. All this happened in what is known as Miocene time, one of the short periods of the geologist's scale. In the fulness of time the volcano died, the rocks cooled and ice, snow and running water began their devastation. The outlet to the lake was cut down, and the stream cut its way through the lake beds, which had by this time turned to rock, and exposed the stumps, leaves and insects. The crater of the old volcano was washed away and rounded off. Ages passed, man came and discovered gold in the rocks filling the throat of the old volcano, founded his mining camps of Cripple Creek and its satellites and drove his little shafts three thousand feet deep into the rocks.

How long even these shorter periods were may be feebly shown by another illustration: In the oceans and in many of our fresh

waters grow tiny plants known as diatoms. They have marvelously beautiful skeletons of silica, which remain after the softer part of the plants decays. The skeletons are so small that 30,000,000 of them would make only a cubic inch, and even that would be mostly cavities, yet at Lompoc, California, they form beds 1,800 feet thick. The beds were formed during Miocene time, probably while the redwoods were growing at Florissant. Nobody knows just how fast diatoms can grow, nor how fast they can accumulate, but it seems probable that they could not deposit annually more than fifteen or twenty deep, making a layer about one sixteenth inch thick. If they grew at Lompoc at this rate then it took about 350,000 years for the entire deposit to form. But this was by no means all of Miocene time.

These things give us a glimpse of time gone, but not an understanding of it. Down in the Grand Canyon the river has laid bare muddy sandstones of Permian age, which, had they been deposited in the same column, would be thousands of feet below the diatoms of which I have just spoken. In these sandstones are tracks of some huge unknown animal, and the tracks lead directly under the rocks a thousand feet below the top of the canyon—"footprints on the sands of time," inconceivably old, marching into the darkness of the ages, a fitting figure of our efforts to look into the past.

Not until the nineteenth century did scientists really attempt to estimate the age of the earth. Data on which to found an estimate had been too few and too uncertain. By that time, however, great numbers of sections of the sedimentary rocks had been measured, and many observations had been made on the rate at which the streams were moving the surface of the land into the oceans. The problem was attacked by various investigators from various angles, but all were practically agreed on a few important facts that would serve as foundations. In general they agreed that:

At one stage in its earlier history the earth was a molten mass, which slowly cooled.

After it had cooled below the melting point of the rocks a crust formed, and after the crust cooled below the boiling point of water, the water as rain and later on as snow and ice began to attack the rocks, as water is doing today, breaking them down and moving the material, partly in solution, partly as visible particles of clay, sand and gravel, toward the ocean.

The material carried into the ocean in solution largely remains in solution, but the solid particles formed beds or strata of shale, sandstone and conglomerate totaling many miles in thickness. At the same time the remains of animals living in the ocean formed beds of limestone.

Movements in the crust of the earth have caused the strata thus formed to be exposed as dry land, where they may be examined by man.

A number of scientists attempted to solve the problem of the world's age by estimating the time required to deposit the sedi-

ments in the ocean, but the estimates of the thickness of the sediments varied from twenty miles to a possible one hundred miles, and the estimates of the rate of deposition varied as largely. Other scientists attacked the problem by estimating the quantity of salts in the ocean. Many careful analyses of river waters, showing what salts they carried in solution, were at hand, and many analyses of ocean water were made. From these figures and from measurements of the rate of flow, the quantity of salts carried to the sea annually by all the streams and the total salts in the ocean were estimated, and these results were used as a basis to determine the time required to accumulate the oceanic salts.

All these estimates had reference only to the age of the earth since it cooled. As would be expected from the number of unknown factors, the results varied widely and ranged from 3,000,000 to 1,600,000,000 years. The largest figure was obtained by W J McGee, of the United States Geological Survey, and came remarkably close to some of the most recent estimates, though at that time it was considered to be entirely out of reason.

In 1896 the world was startled by the discovery of radium, an element that is constantly breaking down and forming new elements. In the intense research that followed this discovery it was found that radium is a product of the disintegration of uranium, one of the rare metals, and that the final product of a series of changes is lead. It was also found that the element thorium is disintegrating in exactly the same way and that it, too, gives lead as a final product. Of the greatest importance was the discovery that in no way is it possible to vary the rate of disintegration; it is always the same.

During the disintegration of both uranium and thorium, atoms of helium are thrown off. Helium is a very light inert gas, that is, it is a gas that combines with nothing else, so that it is non-explosive, and for this reason it is used in our newest dirigible, the Los Angeles. It is these atoms of helium, thrown off at tremendous velocity, that cause the luminous figures on your watch to glow or makes shining spots that show you after dark where to find the chain pull or the switch for your electric light. When a uranium atom has thrown off eight atoms of helium it becomes lead; likewise a thorium atom becomes lead when it has thrown off six atoms of helium. The number of helium atoms thrown off in a given time by radium was counted, and the rate of production of lead from uranium per year was calculated. For the first time a real measuring rod of known length was put in the hands of scientists with which to calculate the age of the rocks, for the lead formed from uranium or thorium would remain in the minerals unless removed by outside

agencies, and if the quantity of uranium and of lead in a mineral is determined the calculation of its age becomes a comparatively simple matter.

Like the teeth of a horse or the rings of a tree, the lead that the minerals contain tells their age.

Taking these minerals as a guide, the investigators have found that some of the rocks are surprisingly old. A youthful uranium deposit at Lusk, Wyoming, is found to be about 32,000,000 years old. Minerals in the prime of life from Glastonbury and Portland, Connecticut, are about 340,000,000 years old; those from Branchville, in the same state, are slightly older brothers, the difference in their ages being only 90,000,0000 years. Minerals from Ontario, Canada, have reached maturity and are apparently 1,300,000,000 years old.

We don't know how far back toward the beginning of the world these figures go. Possibly half way—maybe more, maybe less. The subject still needs study, and the National Research Council has appointed a Committee on the Determination of Geologic Age through Atomic Disintegration to take up the matter. And at some future time we shall hope to discuss this subject further with you.

WEIGHING THE EARTH

By Dr. PAUL R. HEYL

BUREAU OF STANDARDS

HAVE you ever wondered, when you have seen men excavating the cellar of a building and taking away the earth a ton at a time, how many tons there might be in the whole earth? Scientific men are the greatest wonderers to be found anywhere, and they have not only asked themselves this question (there was no one else to ask) but they have devised experiments to give the answer. It is, of course, a very large figure; about six thousand million million million tons; six followed by twenty-one ciphers. The number is really known a little more accurately than that; the first three figures are known, if any one should need them, and experiments are now in progress at the Bureau of Standards which, if all goes well, will give the fourth figure.

But why should any one need to know this number at all? Of what possible use can it be to anybody?

There are two answers to this question.

In the first place, a knowledge of the mass of the earth is of interest to astronomers, for it is a starting point from which are

obtained the masses of the moon and of the sun and of the other planets of the solar system. Our earth, therefore, is a natural standard of reference with which other quantities are compared; and it is the business of the Bureau of Standards to determine such fundamental reference quantities as accurately as possible.

In the second place, a knowledge of the earth's mass enables us to learn something about the interior of the earth, that region about which so much imaginative literature has been written, and which no one can ever hope to investigate directly. From the earth's mass we can calculate its density, that is, the number of times it is heavier than an equal globe of water; and this leads us to a rather remarkable conclusion.

The various rock materials which make up the outer layer of the earth, which are accessible to test and measure, turn out to have an average density between two and three times that of water, while, curiously enough, the figure for the earth as a whole comes out about twice this value. The inference is obvious: the core of the earth must be composed of something much heavier than the outer crust.

What can it be?

For this question, too, it is possible to find an answer. Several lines of argument, including the speed of travel of earthquake waves, the phenomena of terrestrial magnetism and some others, have led those who have given most attention to the subject to the strange conclusion that the core of the earth is a great ball of iron!

Occasionally there fall to the earth bodies called meteorites, which are often composed of metallic iron, sometimes with a stony admixture. These strange bodies seem to be floating about in space, and occasionally one of them comes near enough to the earth to be drawn in by its attraction. The idea is that the earth is like a great meteorite, or the result of the accretion or massing together of many such particles, in which process the heavier iron portions have gone to the center by virtue of their own weight, or attraction for each other, while the lighter stony portions formed the surface layers. The meteorites that fall to earth may thus be regarded as chips left over or unused portions of material.

So much comes out of an apparently dry and abstruse determination of a numerical constant of nature!

How is the earth weighed? Like many other scientific measurements, this operation is carried out by a roundabout process.

The first thing to do is to set up a miniature system representing the earth and a body near its surface, and determine by experiment the actual force of attraction between these bodies. This force de-

pends on several things: in the first place, on the masses of the bodies, greater bodies attracting each other with more force than smaller ones; and second, on the distance between their centers, bodies attracting more strongly the closer they are together. All these quantities are measured in the miniature system: the masses of the two bodies, their distance from each other and the force of attraction between them.

In the actual case of the earth and a body on its surface, we can measure all but one of the quantities involved. We can weigh the small body and thus determine the force with which the earth attracts it. We can determine by the same operation the mass of the small body, and we know the distance from its center to the center of the earth. What we do not know is the mass of the earth. But by applying the results of our miniature experiment, in which every quantity was known, and solving a problem in proportion, we can calculate the mass of the earth.

The most difficult part of this experiment is to determine the force of attraction between the miniature earth and the small body attracted by it. Even with a mass of steel weighing 140 pounds (which is used in the arrangement employed in the experiment now in progress at the Bureau of Standards) and a ball of gold weighing an ounce and a half the force is measurable only in millionths of a grain, in metric units, about a thousandth of a milligram.

To determine this very small force with the necessary precision an arrangement called a torsion pendulum is used. A light rod of aluminum about eight inches long is hung by a very fine filament of tungsten at its center. This filament is such as is used in incandescent lamps. The rod hangs in a horizontal position and carries at each end a gold ball. The rod swings very slowly back and forth in a small arc, with a time of swing of about half an hour. So delicate is this arrangement that a very small force applied to the balls will perceptibly alter its time of swing.

The swinging system is enclosed in an airtight case from which the air is exhausted. This eliminates trouble from air currents which might disturb the swing and also allows the system to swing for a long time before coming to rest.

Outside this case the two large steel masses are placed, at first as close as possible to the gold balls inside. In this position the time of swing of the torsion pendulum is measured. The steel cylinders are now moved as far away as possible from the balls and the time of swing again measured. Due to the diminished attraction of the steel masses for the gold balls at the greater distance, the time of swing is now found to be about five minutes greater.

From observations such as these the actual force of attraction between the steel cylinders and the gold balls can be calculated.

So delicate is a well-arranged torsion pendulum of this character that the presence of a person within ten feet of it will alter its time of swing because of the attraction of the person's body for the gold balls; or if a car is driven up outside the laboratory and parked the torsion pendulum will indicate its attraction. To avoid disturbances of this nature the apparatus is set up in a room thirty-five feet underground, where all moving masses are overhead, and have no effect on the pendulum.

This is not the first time the earth has been weighed. By the use of apparatus similar to that which has just been described this experiment has been conducted several times in the past century, with results of increasing precision as the technique of laboratory practice has gradually been perfected. No work of this kind has been done for a generation, and it has been thought that sufficient progress has been made in that time to warrant the attempt to obtain another figure of the weight of the earth.

About thirty years ago a piece of work of this kind was performed which has about it so much of human interest that it may be told here profitably.

As has often happened, two men worked on this experiment at the same time without knowing of each other's doings. One of them was a British scientific man, Professor Boys, who worked with the best facilities that London and Oxford University could furnish him. He spent several years at the task and obtained what was believed to be the most accurate figure obtained up to that time.

While he was doing this, another man, of whom Professor Boys had never heard, was working at the same problem hundreds of miles away in Bohemia. This man was Dr. Karl Braun, who had been a Jesuit teacher of physics all his life. At an advanced age he retired from teaching and was sent to a monastery in the mountains of Bohemia to end his days peacefully and quietly. But Dr. Braun could not content himself in inactivity, and for something to do set up an apparatus in his cell in the monastery and determined the weight of the earth. His result, when published, was almost exactly that obtained by Professor Boys.

Much of Dr. Braun's apparatus was made by himself. It is noteworthy that he was the first person to use a vacuum about his torsion pendulum with success. Professor Boys, in his published paper, said that he believed the use of a high vacuum to be impracticable.

Professor Boys could hardly credit Dr. Braun's achievement, and made the long trip to Bohemia to see him. He found Dr.

Braun, at that time over eighty years old, planning a repetition of his work to eliminate some errors which he had recognized. Unfortunately, he did not live to do this.

A few years later, Dr. Burgess, the present director of the Bureau of Standards, carried out an experiment of this nature involving several novel features at the Sorbonne in Paris. He did not, however, succeed in improving upon the figure obtained by Boys and Braun. Since that date no work has been done on the question, until it was taken up again, under the auspices of Dr. Burgess, at the Bureau of Standards.

Nothing, it would seem, is too large or too small for men to attempt to weigh and measure. In this experiment that I have just described to you both extremes are to be found. The enormous mass of the earth is determined by measuring a force so small that only the most delicate pendulum known will detect it.

The enormous distances from the earth to the sun or to the stars do not appal the mind of man; neither do the inconceivably minute quantities involved in the study of the structure of atoms. Anything that exists is a fit object for study, no matter how large, no matter how small. Man may be but the merest speck in the universe, yet in his intelligent comprehension of it he is but little lower than the angels.

It is said that at one time an astronomer discovered a new star, which appeared to be approaching the earth with a great velocity. Night after night he studied it, finally becoming convinced that it was destined to strike the earth. He calculated that this would happen within a few years. Night after night he watched this approaching doom, fascinated by it. He did not announce his discovery, fearing to witness the orgy of lawlessness and despair into which it might plunge the world.

One night he spoke aloud and addressed the star as follows:

> I know that you will soon destroy me and all things living. I can calculate the day, nay, even the hour when this will happen. Yet you are but a blind, brute thing, and I would not change places with you!

RADIUM

By Dr. S. C. LIND

U. S. BUREAU OF MINES

In 1898 a new metal was discovered in Paris by Professor and Madame Curie. Because it was found to give out certain kinds of rays continuously they called it radium. In fact, it was by means

of these rays that the discovery was made. No other chemical element has ever attracted so much popular and scientific attention. Entire institutes have been devoted to its study. Medical clinics have been founded for its therapeutic use. Industrial companies have been formed and plants erected for its commercial production. Millions of dollars have been invested in it, and yet the entire output—all the radium that has been extracted in the world—would weigh less than ten ounces and could be put into a small teacup.

What are the remarkable properties of radium which attract so much attention? Scientifically its discovery represented much more than finding merely another new element. Radium is an entirely new kind of matter. Before its discovery it was thought that the chemical elements, about ninety in number, of which all substances are composed, were immutable. The alchemists spent a century of vain endeavor to transmute the metals. Their failure resulted in the belief that the elements could neither be destroyed nor changed one into another.

The early studies of radium disclosed apparent contradictions to this and other natural laws. Radium was found to evolve heat continuously and to emit rays and high velocity particles which produce electrical charges in surrounding matter. These new phenomena remained unexplained until 1903, when two British scientists, Rutherford and Soddy, proposed the theory of atomic disintegration. This theory has been proved correct. According to it the heaviest elements are in a state of evolution or change into others of lower atomic weight. This change is accompanied by the emission of rays. The two heaviest metals, uranium and thorium, were well known long before the discovery of radium, but it was not even suspected that they were slowly changing to lighter elements. Each of them is the parent of an entire family or series, consisting of a dozen or more members. Radium is merely one of these members, about midway in the uranium family. The moment of change from a parent element to the offspring is all-important, for it is at this time only that rays are given off. In fact, they are the necessary accompaniment or cause of the change. Since very small quantities of matter contain billions of atoms, some of them will always be changing at any instant, and so the change appears continuous and uniform, though it is really made up of a large number of separate events.

The time required for half of any quantity of an element to change into the next lower species is called its half-life. For example, the half-life of radium is about 1,600 years, meaning that if 1,600 years ago one had had one gram, one ounce or any other

quantity of radium, one half of it would now remain. This is not to be understood to mean that in the next 1,600 years the remaining half would entirely disappear—only one half of that half, or one fourth, would change and in the next 1,600 years one eighth, and so on. Pb is the final member and hence accumulates in all U and Th minerals. Uranium and thorium have very long life-periods—several billion years. If they changed more rapidly they would have disappeared long ago during the geological ages through which they have existed and would not now be found in nature.

If radium is then merely one of many similar radio-elements, why does it have such especial interest? The answer is an unusual one. It is one case where mediocrity excels. The importance of radium arises from the fact that it has a half-period of about 1,600 years, which is intermediate among half-periods distributed all the way from a short fraction of a second to billions of years. If the life of radium were very long, like that of uranium, it would be so inactive that it would take an inconveniently large amount to give off a required intensity of rays. It is not possible to use several carloads of ore in a clinic. On the other hand, if the life of radium were very short, like that of some of the other radioactive elements, it could not be retained long enough for it to be profitable to produce or purchase it. It is therefore its moderate span of life, neither too long nor too short, which makes radium valuable. Radium has only once been prepared in the form of the pure metal. It is more convenient to prepare and use it in the form of its compounds or salts—radium chloride, bromide or sulphate. All these when first prepared are white, like table salt, and in ordinary daylight look equally harmless, but after a few hours a darkening in color indicates that something unusual is taking place. This change in color is produced by the rays themselves, and has no especial significance, but on observing a radium salt in the dark a continuous will-o'-the-wisp glow is manifest, and if any part of the human body be exposed to it too long or intensively, a deep-seated injury like a burn will result a few days later, though no sensation of pain is experienced at the moment.

It was this experiment performed by Pierre Curie on himself which suggested the therapeutic use of radium, which has come to be of great value in the treatment of cancer and other diseases.

In such treatments radium is generally used directly in tubes containing its salts. This method exposes the radium to the danger of loss, accident or theft in the clinic. Occasionally patients have swallowed the tubes, necessitating an operation to save both the radium and the patient. The newer and better practice is to retain

the radium in the laboratory in solution and to collect from it a gas—radium emanation or radon—which has all the desirable radiating properties of the parent salt. Since this gas is fairly shortlived, it must be collected anew from the solution at short intervals—daily in the larger clinics. The gas is continually regenerated from the stock solution of radium and hence its loss would not be serious. The therapeutic use of radium has now become common in many of our larger hospitals, and by far the greatest proportion of radium that has been produced has gone into therapeutic use.

The only other important use of radium is that in the luminous paints, such as are used on illuminated watch and clock dials. The base of these paints is a specially prepared zinc compound called phosphorescent zinc sulphide, because it glows in the dark after exposure to light. Unfortunately, this afterglow from ordinary light will last only an hour or two, so that radium must be added to the paint to produce a continuous glow.

During the war, luminous paints came into very general use on wrist watches and other dials which had to be visible without disclosing a light to the enemy. An aeroplane control board has eight or more dials which must have a paint of high radium content to give sufficient luminosity for twilight flying, while it is too dark to see well, but before the eye has become sensitive. New uses for radium paint are continually being found, as on electric switches, push buttons, drop cord pendants, numbers on Pullman berths and theater seats, keyholes or on any object which it is desired to find or to avoid in the dark.

These luminous paints have a fairly long life—several years at least, but at best far too short to justify the use of radium with a half life of 1,600 years. The use of a similar radio-element obtained from thorium, called mesothorium, is preferable when it is available. Mesothorium is now substituted in part for radium in luminous paints, where, on account of its short life, it is far more suitable than in therapeutic use.

The production of radium on a commercial scale was first begun in Austria from the pitchblende of the Joachimstal Mine. Pitchblende is a black oxide of uranium, which, like most other uranium minerals, contains one part of radium to three million parts of its parent uranium. The Austrian ore was of such grade that it could be profitably worked, and prior to the world war two to three grams were produced each year from this source. The cost varied from $80,000 to $160,000 per gram.

Just about the beginning of the war, in 1914, the center of radium production was shifted to the United States, through the

development of a new uranium ore called carnotite. Carnotite occurs in fairly large quantity in certain sandstones in Colorado and Utah. Unfortunately, it is not a rich ore in radium content, and since it occurs in remote districts, where mining operations are expensive, the cost of producing radium from it was quite high. In spite of these difficulties the industry had a remarkable development, owing to the energy and courage of those who entered it before and during the war. The Standard Chemical Company, of Pittsburgh, was the pioneer and has to date produced more than half of the world's supply of radium. The United States Bureau of Mines was the next earliest producer in this country. Later the Radium Company of Colorado and the Radium Luminous Materials Corporation and several smaller companies entered the field. For several years the production in the United States from carnotite was on a large scale, ten to fifteen times that of Austria. In 1921, 35 grams were produced in the United States. During the war the price reached $125,000 and occasionally $135,000 per gram. After the war it became stabilized at $120,000, except for occasional sales of large quantities at lower prices.

A price of $100,000 for a half thimbleful of material seems on first thought fabulous and has been regarded by many as exorbitant. But when one considers that in order to produce one gram of radium, which would in the final pure state be about a half thimbleful, it is necessary to mine from 200 to 500 tons of ore, which frequently has to be packed on burros and then hauled 60 or 80 miles to a railway and then be shipped from 500 to 2,000 miles by rail, and that an equal weight of chemicals is consumed in the extraction of radium, not to forget the expense of labor and of a highly trained staff of specialists, a different idea is obtained. As a matter of fact, the price of radium has always been based on cost, quite as rigidly, if not more so, than for most mineral products.

About three years ago the discovery of a new source of high-grade radium ore in the Belgian Congo was announced by the owners, the Katanga Copper Company of Belgium. Owing to the high grade of the ore, which is principally pitchblende and kasolite, and to favorable conditions for mining it and for working it up in Belgium, the cost of production was lowered to a point at which American carnotite can hardly compete. The price was reduced from $120,000 to $70,000 per gram. The United States Radium Corporation, of New York, has been the only company to continue to produce from American carnotite. The Standard Chemical Company still maintains its medical service and sales organization for the distribution of the Belgian product. For a time, at least, American production is largely suspended.

Curiously, this drop of almost one half in the price has not stimulated sales of radium, but has had the opposite effect. In 1923 about 18 grams were sold, and in 1924 only about 10 grams. This is probably not attributable to saturation of the American market, but rather to hesitancy on the part of the prospective purchaser, fearing that his investment may be jeopardized by a further reduction in price. The Belgian Company has announced no definite future policy, but a further reduction in price does not appear to be immediately in sight, if at all. It is reported that the Belgian plant is now closed on account of over-production. Since the American market is the principal one for the sale of radium, it is believed our willingness to purchase will be the controlling factor. Apparently, the uncertainty of the situation brought about by the Belgian discovery is at present the only deterrent factor in the sale and use of radium.

EARTHQUAKES

By SIDNEY PAIGE

U. S. GEOLOGICAL SURVEY

EARLY in March there was felt in the northeastern United States an earthquake, the origin of which lies perhaps in Maine, perhaps in Canada. It was felt in New York City, in New Haven and at other places. Various accounts have appeared in the daily press—an excellent one in the New York *Times* of March 8.

Shortly before this quake occurred it was proposed that I broadcast a brief account of earthquakes. Let me heartily congratulate the managers of WCAP for arranging the recent shocks. Their advertising department is apparently 100 per cent. efficient, but their evident close association with the powers of darkness is very discomfiting. One hesitates to think what would happen should they propose a talk on hell fire and eternal damnation and advertise the subject with equal efficiency.

An earthquake is exactly what the word indicates—a quaking of the earth. The violence of the quake at any place is in general directly proportional to the violence of the disturbance at its origin and to the distance of the place from this origin.

It has long been recognized that certain regions of the earth's surface are particularly subject to earthquakes and that in certain other districts earthquakes rarely if ever happen. Between these extremes there are all possible degrees of earthquake visitation.

Furthermore, in a region or country that is subject to earthquakes (Japan, for example, or Italy) there are many districts

which are hardly ever visited by perceptible shocks. This fact in itself is sufficient to suggest that earthquakes have a very definite local cause. Broadly viewed, the principal earthquake regions of the world are situated along certain continental borders or in other regions where we know geologic changes in connection with mountain growth are relatively rapid and now in progress. Thus all around the Pacific Ocean there is a succession of seismic areas beginning with the East Indies and passing north and east by way of the Philippines, Japan and Alaska and then south along the west coast of the two Americas. Another well-marked region begins in the west of Europe and passes east through Sicily, Italy, Greece, Syria, India and Central Asia. The West Indies constitute a district which may be taken along with Central America. In these regions are contained practically all the known localities subject to pronounced earthquake activity. Note that the phrase "*pronounced* earthquake activity" is used, for earthquakes do occur in other regions but far more rarely. If you examine a globe of the earth you will find that the great earthquake zone that follows the Pacific border is almost an arc of a great circle. In reality, you do not *cross* the Pacific in going to Japan—you *follow the coast* along an arc that is remarkably straight, considered on a large scale, from the southern tip of South America to the East Indies and Australia. The second earthquake zone likewise has this characteristic of nearly following a great circle, though its direction is quite different from the first. Both of these great earthquake belts are very *mountainous* belts, are major topographic features of the earth's surface, and are regions of great instability of the earth's crust. At many places these high mountains are bordered by oceanic deeps, and it is within this zone between ocean deep and high mountains that adjustments of the crust of the earth are now taking place.

Perhaps 99 per cent. of earthquakes that are felt are due to movements of the earth's crust along faults, which are really nothing but cracks—that is, they are due to adjustment in the equilibrium of the crust as a whole, along lines of weakness such as have just been described. These zones of weakness (where faulting—that is, breaking—takes place) may be attributed to stresses accumulating during a vast extent of time and caused by the force of gravity constantly seeking to adjust the balance of an unequally weighted crust. Just one example of how this balance is being slowly but continually upset: You may readily see that the continual transfer of material by the Mississippi River from its broad drainage basin to the delta at its mouth is necessarily bringing about a redistribution of weight on the outer crust. Ultimately there must be re-

sponse to the weight of such a deposit. If the globe is actually shrinking, due to transfer of heat or changes in density, obviously the outer crust will be constantly deformed. The complex folding and faulting of the surface rocks in many places supports this view.

Active volcanoes are formed at many places along the great belts of weakness just referred to, but they should be thought of as *results* of the adjustments going on and not as the cause.

How is the shock of an earthquake transmitted? The rocks are strained until the limit of their elasticity is reached, when they suddenly break—either along an old fault or on a new one. The friction along the fault plane is enormous, and as the surface on one side drags against the other vibrations are set up that travel outward as a succession of waves. Likewise the actual elastic rebound of the earth block on the two sides of the fault starts a wave that travels outward. The speed of these waves is great and the surface of the ground is actually set in violent motion. It is this motion that we feel as the shock, and in general the nearer one is to the origin of the disturbance, the more violent the shock. A violent shock may be recorded on delicate instruments completely around the globe.

If a shock originates by vertical faulting beneath the deep sea, a water wave that travels with great speed starts outward. Such a water wave in approaching the shore, over a gradually shallowing bottom, may attain great size and cause great damage to towns built at sea level. The sea may be withdrawn at first but may return with great violence. Such waves have proved disastrous on the west coast of South America, at Lisbon, Portugal, and at many other places.

The destructive effects of a great earthquake in a thickly populated district are appalling. The disaster is often intensified by fire, and if the district is exposed to the sea, great waves may add to the horror of the occasion. In the city of Lisbon, Portugal, sixty thousand people were killed in less than five minutes by the collapse of nearly all buildings, and an hour later great waves from the sea thirty to sixty feet high inundated the city, adding to the destruction. Lima, Peru, was destroyed by an earthquake, and on the evening of the same day the sea rose in a wave eighty feet over the port of Callao, on the coast. Out of twenty-three ships in the harbor, nineteen were sunk and four others were carried far inland.

The recent earthquake in Japan (September, 1923) was accompanied by fires in Yokohama and Tokyo that were the most disastrous recorded in human records. The property loss is estimated in billions of dollars and lives in hundreds of thousands.

Slight earthquakes leave little or no trace on the surface of the ground; violent earthquakes produce startling changes with great suddenness. The San Francisco earthquake was caused by the sudden rupture of the earth's crust along a fault zone known as the San Andreas rift, for a distance of 270 miles. The fault unaffected by movement can be traced much farther. The displacement was such as to cause the country on the southwest side of the rift to move northwestward relatively to the country on the northeast of the fault line. The movement was largely horizontal and in places as great as twenty-one feet. As a result all the fences, roads, railways, bridges, tunnels, dams, pipes and other structures which cross its path were dislocated. Inasmuch as the movement of the earth which caused the fault was not confined to its immediate vicinity, but was distributed over a considerable belt of country on either side of the rupture, the latitude and longitude of a large portion of the coast ranges of California were changed, and resurveys have been necessary.

In the recent Japanese disaster of 1923 marked changes of level occurred along the coasts of Sagami and Tokyo bays, and soon after the earthquake a resurvey was made of Sagami Bay. It revealed three areas of depression and three of elevation. The maximum subsidence was found to be 1,554 feet, the maximum elevation 810 feet. Some of this change, however, may have taken place before the earthquake.

It is reported that in the whole earthquake area 128,266 houses completely collapsed, 126,233 half collapsed, while 447,128 were burned and 868 were swept away by the sea waves. Along the shores of Sagami Bay the percentage of houses that collapsed was extraordinarily high—84, 95, 96 and 97 per cent. at four different places. So complete destruction was due in part to the nature of the sites on which these towns were built. In Tokyo the intensity of the shock was three times as great on soft soil and "made ground" as on the harder ground elsewhere. The effects of this great and sudden shock on different kinds of buildings provide useful warnings for the future. Brick buildings crumbled down at once into ruins; wooden buildings, of which so large a part of Tokyo was built, withstood the shock fairly well but were an easy prey to the fires that followed. The modern steel-brick buildings offered a stout resistance to both earthquake and fire, and it is natural to conclude that the new Tokyo and Yokohama will, as far as possible, be cities of steel-brick houses.

Earthquakes can be predicted only in general terms, and the soundest basis for this prediction is the statistical record of past disturbances. For instance, in Japan, where on the average there

are one or two quakes every day, it is not difficult to predict an earthquake for the country as a whole. But to indicate exactly where and when it will occur is at present impossible. In most of the eastern United States, therefore, where earthquakes are so rare, even an approximate guess as to time or locality can not be made. And it is equally hazardous to assert that a disastrous quake will never occur. In other words, the earthquake risk varies greatly from region to region, and in respect to this risk the eastern United States is very favorably placed but is certainly not immune from the possibility of a severe shock, which if occurring in a densely populated district might prove disastrous.

Interest in earthquakes in this country was greatly stimulated by the San Francisco disaster, although in Japan the subject had been seriously studied for many years. The engineering aspects of the subject are now receiving much attention. The best types of foundation, the best distribution of weight, the best types of construction are all subjects of inquiry. Protection of water and gas mains is vital. Important aqueducts and dams in the West are being studied with earthquake possibilities in mind. The faults of California are being mapped with respect to their past and probable future activity.

In closing I wish to call attention to certain social aspects of the earthquake problem. There is nothing to be gained by minimizing the earthquake risk in regions where the risk is high. Attempts to suppress information or discussion or study, on the ground that business will be adversely affected, are not only shortsighted but useless. Pressure of increasing population is so great and is growing so rapidly that all places favorably located for commerce will always be thickly populated, and thus business will always be carried on. Tokyo and Yokohama will be rebuilt. Therefore business men should strongly support all earthquake inquiry. Scientific earthquake investigation will ultimately properly evaluate risk, as statistical data accumulate and as geologic investigation continues. Engineering skill will improve construction, structures will be more favorably placed with respect to foundations, and materials will be better adapted to the stresses that they must withstand under an earthquake shock.

The word seismology, meaning the study of earthquakes, is derived from the Greek word for earthquake. Instruments to detect and measure the intensity and nature of earthquake movement are called seismographs. Such instruments are widely distributed over the world. The mechanical problem to be solved in order to measure earthquake motion is to maintain a point that will remain *steady* while the earth vibrates. Then a suitable pencil attached to

the steady point will register the vibration of the earth, if a suitable surface is provided on which this vibration can be recorded. Books have been written on methods of doing this. There are many such instruments in the United States and in other parts of the world.

With a number of these instruments supplemented by other data it is possible to locate very accurately the origin of earthquake shocks. The practical and theoretical value of the accumulating records in seismological laboratories, interpreted as they are with ever-increasing knowledge, is very great. Much is being learned that will at least alleviate earthquake disaster, and much is being learned regarding the constitution of the deeper portions of the earth.

The Seismological Society of America, with headquarters at Stanford University, California, is doing splendid work in this connection.

WHERE ARE THE STARS?

By Dr. C. G. ABBOT

SMITHSONIAN INSTITUTION

We see less than 5,000 stars with the naked eye. On clear moonless nights, a cloudy belt called the Milky Way encircles the heavens. A telescope shows that this is really a multitude of stars. It lies in the plane of greatest extension of our heavenly host. Although only three or four thousand stars can be seen by the naked eye, the telescope proves that there are really thirty or forty billion of them, ten times as many, for instance, as there are dollars in the budget of the United States government, and twenty times as many stars as there are living people in the world. They do not extend indefinitely, but lie in a limited extent of space of the general shape of a watch or lens. How big is it?

To know that, we have to find a way to measure tremendous distances. We begin with the sun. The sun is a star. If he were carried away to the next nearest star, Alpha Centauri, which is visible in South America, but not in the United States, the sun would be a twinkling point of light, and only as bright as Altair. We have to know his distance to learn more about the distances of the others.

There are many ways to measure the sun's distance. They agree so well that there can be no doubt that we know it within about a tenth of one per cent. I shall tell you first about the velocity of light. Dr. Michelson, now of Chicago, and a winner of the Nobel prize, was a midshipman in our navy when a young man. He car-

ried out measurements of the velocity of light here in Washington with the late Professor Simon Newcomb. They used a mirror revolving very rapidly at a measured speed. A beam of light, reflected by the moving mirror, traveled across the Potomac River, was reflected back, hit the moving mirror a second time, and was reflected towards the original source. But while the light traveled, the mirror turned. So the reflected beam did not return exactly to the source, but a little to one side. From this displacement, they computed the velocity of light. It came out 186,330 miles per second.

The planet Jupiter revolves round the sun like our earth. Jupiter, as you may see with a small telescope, has several moons. These moons and Jupiter shine by reflected sunlight just as our earth and its moon also do. When one of Jupiter's moons gets behind the planet, it is eclipsed, just as our moon is when it gets behind our earth, out of sight of the sun. Astronomers find that the eclipses of Jupiter's moons take place 16 minutes 37 seconds later when the earth is on opposite sides of the sun from Jupiter than they do when we are on the same side. You will see at once that the eclipses of Jupiter's moons occur 16 minutes 37 seconds later because the light that tells us when they occur has to travel just the diameter of the earth's orbit further at one of these times than at the other.

But in 16 minutes 37 seconds there are 997 seconds, and light travels about 186,000,000 miles. So the sun is half that distance, or about 93,000,000 miles away. This is not the best way to measure the sun's distance, but perhaps the easiest to understand. All the other good methods give nearly the same result.

When a surveyor measures a very long distance, he takes two stations a convenient known distance apart, and setting his instrument at both, he measures the angles of his triangle whose three corners are the two home stations and the distant point.

In applying this method to measure the distances of the stars, the diameter of the earth is too small a base line. But as the earth goes round the sun in twelve months, it occupies stations 186,000,000 miles apart in January and July. Surely that immense distance between the home stations ought to be enough. It answers for only a few hundred among the stars. With the very nearest star to the sun, Alpha Centauri, the total angle it appears to pass over as we swing from one side to the other of the earth's orbit is only 1.6 seconds of arc. This is about the same as the width of a telegraph wire seen a half mile distant. The distance of Alpha Centauri is about twenty-five millions of millions of miles. It takes light, traveling 186,000 miles a second, more than four years to come to us from Alpha Centauri, but only eight minutes to come from our sun.

To measure star distances in this way, astronomers now use photography exclusively. They photograph the chosen star against his background of very faint stars, which are many times as far away. Similar photographs are made at intervals of about six months. By exact measurements of the distances of the chosen star from his faint neighbors, the little displacements due to the earth's motion are finally determined. But if these displacements are much less than 1/100 second of arc, they are too small to measure. Therefore, there can be no certainty by this surveyor's method as to star distances that require of light more than five hundred years to travel.

This does not begin to get us to the ends of our starry system. Nevertheless, just as the distance of the sun gives a starting point towards the nearer stars, so their distances give a starting point for the rest. It has been a great boon that men like Dr. Schlesinger, of Yale; Dr. Mitchell, of the University of Virginia; Dr. Van Maanen, of Mount Wilson Observatory, and others have conferred by making nearly 2,000 such star-distance measurements in the last fifteen years.

Our sun, with the earth, the moon, all the planets and their moons, is traveling about twelve miles a second towards the bright northern star, Vega. All the other stars like the sun are traveling, too, but in all directions. Refined measurements show these so-called proper motions of the stars, but we have to wait many years to measure them accurately. A proper motion as large as a second of arc in a year is very rare. Still thousands of the stars' proper motions are accurately known. Now it will be clear that if a star which seemed to move a second of arc per year was carried twice as far away from us, his motion would then seem to be only a half second per year. So the proper motions diminish in direct proportion as the distances increase.

If, now, we consider all the stars whose distances have been measured, we shall be able to find the average proper motion which suits a standard distance. Then, let us group all the stars according to apparent brightness. If a large group of stars has an average proper motion ten times less than the average proper motion corresponding to the standard distance, we know that stars of that group are ten times the chosen distance away. There are several pitfalls to be avoided that I haven't time to explain, but I'm sure you all catch the idea. In that way Professor Kapteyn and his successor have found for us the average distances of a group of stars of given brightness.

Working by wholesale like this, we can go as far as we please, even to stars so distant that light requires many thousands of years

to come to us from them. This is the way the shape of our star system has been worked out. It is found to be a flattened disk, like a watch or a lens, perhaps 10,000 light-years thick, and 100,000 light-years in diameter. Still it is not satisfying to have to work altogether by wholesale. We need many individual star distances, too.

About ten years ago, Dr. Adams, of Mount Wilson Observatory, and his colleagues discovered a powerful method based on the use of the spectroscope. The stars give rainbow-colored spectra with thousands of dark lines crossing the band of color. Some of these dark lines, as Dr. Adams found, vary in their intensity of shade according to the absolute brightness of the star that produces them. By absolute brightness, I mean the rank a star would have among the others if they were all at equal distance. You will ask how Dr. Adams could know the absolute brightness. He could know it only for stars whose distances had been measured. But there were enough of them to show exactly how these sensitive spectrum lines change, depending on absolute brightness.

Very well. Whenever he observed the spectrum of a star, he measured the intensity of these sensitive spectrum lines. That proved how absolutely bright the star was. Comparing absolute brightness with apparent brightness, he could calculate exactly how far away the star must be. The great beauty of this method is that it makes no difference in its percentage accuracy how far away a star is, provided the spectrum can be well observed. With Adams's method, star distances of many thousand light-years are measurable.

Now we must mention another method very limited in scope, but highly important. There is a kind of stars tremendously bright, and more massive than our sun, which vary in their brightness. They go through a cycle of changes in from one to fifty days. The star Delta Cephei, in the northern constellation of Cepheus, is one. Because of this, these are called Cepheid variables. The distances of a good many Cepheids are known. Dr. Shapley, director of Harvard College Observatory, found that the average absolute brightness of the Cepheid variables was closely related to the period of a full cycle of variation. He was able to draw a curve giving absolute brightness against period of variation. With this curve, one needs only to know that a star is a Cepheid, and the absolute brightness can be found immediately from observing the period of variation. From this and the apparent brightness comes the distance. As the Cepheids vary in brightness in a very special manner, they can be recognized very readily.

Besides the stars, there are in the heavens cloud-like objects called nebulae. Only a few of them can be seen by the naked eye,

the largest of these being in the constellation Andromeda. Several hundreds of thousands of nebulae are visible to great telescopes. It has been a question for over a century what sort of objects they are. Sir William Herschel suggested them to be island universes, that is, other star systems separate from ours. Dr. Hubble, of Mount Wilson Observatory, has proved it.

He photographed the Andromeda nebula. At the outer part, he was able to resolve the cloud-like object into a multitude of tiny stars. They were all ten thousand times too faint to be seen by the naked eye. He found some of these stars to be Cepheid variables. By noting their periods, he found their absolute brightness. Comparing with the apparent brightness, he worked out their distance. They all agreed in giving the distance approximately a million light-years. The light by which we see the Andromeda nebula started towards us before the glacial period and before there were any men on earth. The nebula lies about ten times as far from us as any stars in our system. It is another galaxy of stars. If this is so for the Andromeda nebula, doubtless it is also the case for many others. Indeed, Dr. Hubble has already found others equally distant. Many of them, which are mere points of light, may require a billion years for their light to reach us.

Consider, if you please, about how important a single human individual is. He is one of a race of some two billions, which changes every generation, on an earth which is a hundredth part as large as the sun. The sun is one of thirty billions of stars, which altogether make but one out of hundreds of thousands of galaxies of stars. Some of these galaxies are probably so far removed that the light which reveals them started towards us before the world began.

I thank you. Good night.

THE STATE OF SCIENCE IN 1924[1]

THE WATER IN THE ATMOSPHERE[2]

By Dr. G. C. SIMPSON, F.R.S.
DIRECTOR OF THE METEOROLOGICAL OFFICE

THE dictionary definition of "saturation" is "the state of a body when quite filled with another," and it is usual to think of saturated air as air which is full of water vapor to such an extent that further water can not be added without condensation taking place. This, however, is a wrong conception, for there is no limit to the amount of water vapor which air can contain at any temperature, provided that it is perfectly pure, except that ultimately the molecules of vapor will be so near together that there will be no distinction between vapor and liquid.

We will describe air as saturated when the water vapor it contains is in equilibrium with a flat surface of pure water at the same temperature. This will define the saturation pressure at each temperature, and relative humidities will be given as percentages of this saturation pressure.

It is well known that water can be cooled below its freezing point without becoming ice, and therefore water and ice may exist side by side over a large range of temperature. But the vapor pressure which is in equilibrium with ice at a given temperature is lower than that which is in equilibrium with super-cooled water at the same temperature; that is, air is in equilibrium with ice at a relative humidity below 100 per cent. Thus, according to our definition of relative humidity, the water vapor in air may be in equilibrium with water over a large range of relative humidities according to the physical state of the water present.

CONDITIONS FOR CONDENSATION

It was in 1880 that Aitken first showed that condensation does not necessarily take place in air when its temperature is lowered below that at which the water vapor it contains is sufficient to saturate it (dew point). He expanded carefully filtered air and found that no fog formed even when there was considerable supersaturation. Aitken concluded "that vapor molecules in the atmosphere do

[1] Prepared for the Handbook to the Exhibit of Pure Science, arranged by the Royal Society for the British Empire Exhibition.

[2] Abstracted from *Nature*.

not combine with each other, that before condensation can take place there must be some solid or liquid nucleus on which the vapor molecules can combine, and that the dust in the atmosphere forms the nuclei on which the water vapor molecules condense."

Aitken invented a most ingenious instrument, easy to work and very transportable, by means of which it is possible to count the number of nuclei present in the air. Tests made with this instrument show that nowhere is air free from nuclei. Their number is seldom less than 100 per cc, while in most country places the nuclei rise to thousands, and in cities such as London and Paris the number may be so great as 100,000 to 150,000 per cc.

The general explanation of these observations is as follows. If there were no dust particles present the drops of water would have to be built up from aggregates of water molecules; if a few molecules met together by chance, they would form so small a drop that it could not exist unless there was large supersaturation. If, however, there were dust particles present the molecules of water would be deposited on them, and the radii of the initial drops would be so large that little supersaturation would be required to maintain them.

This explanation appeared to satisfy every one for a long time. In 1912, however, Wigand found that even when he created large clouds of dust he could not find any increase in the number of nuclei in his condensation apparatus. Apparently Aitken's instrument does not measure the number of dust particles present, but the number of hygroscopic particles, and meteorologists are now of opinion that condensation commences on these hygroscopic substances.

Köhler, working in Norway, is tempted to contend that sea-salt provides these particles. It is, however, not necessary to go so far as this, for there are many other sources of hygroscopic substances. Lenard and Ramsauer have shown that sunlight—probably only the ultra-violet part—acts on the oxygen, nitrogen and water vapor of the atmosphere, producing very hygroscopic substances.

Large quantities of material capable of becoming condensation nuclei, however, are produced by all processes of combustion. Thus the household fires and factory chimneys of centers of industry produce vast quantities of nucleus-forming material, chief of which is sulphurous oxide. This, when illuminated by sunlight in the atmosphere, is a very hygroscopic substance capable of causing condensation in unsaturated air. It is estimated that in England something like 5,000 tons of sulphur are burnt each day in coal fires, giving enough sulphur products to pollute the atmosphere from Land's End to John o' Groat's. Other products of combustion are also

hygroscopic; thus it is not surprising that air from large industrial centers contains enormous quantities of nuclei.

When the temperature of the air is below the freezing point, it is inconceivable, owing to the small amount of vapor present, that condensation will take place by the fortuitous meeting of molecules; some kind of nuclei therefore will be necessary.

When sledging in the Antarctic with Captain Scott in 1911 we became enveloped in a fog during sunshine. On the fog opposite the sun we saw a white bow in the position usually occupied by a rainbow. This phenomenon can only be explained on the assumption that the fog was composed of small spheres. But the temperature was – 29° C. (– 21° F.) and almost a dead calm existed at the time; hence these drops could not have formed at a high temperature and then been super-cooled. The only explanation appears to be that in the clear air of the Antarctic, where there are no "dust" particles suitable for condensation available, there are plenty of hygroscopic molecules of some sort.

Haze

Perfectly pure air is almost completely transparent to visual light waves, and if the air were always pure we should see distant objects through air almost as clearly as through a vacuum. But there are always more or less particles of foreign matter present. The action of these particles is twofold: first, they reduce the amount of light reaching the eye from distant objects; and, secondly, in the daytime they scatter the general light of the sky and so send to the eye extraneous light which reduces the contrast between distant light and dark objects on which visibility depends. Generally this foreign matter consists of a mixture of solid ponderable particles and hygroscopic molecules. In perfectly dry air the latter would be practically invisible, but when loaded with water in a humid atmosphere they add to the obscurity of the atmosphere.

Haze is due to this kind of obscurity, and varies in intensity from the slight obscurity of polar regions, which depends almost entirely on the hygroscopic particles, to the dense obscurity of a dust storm in tropical regions, which is due almost entirely to solid particles.

Mist

If the temperature falls below the dew point, the hygroscopic particles are sufficiently large to form excellent nuclei for condensation, and relatively large amounts of water are deposited for small falls of temperature.

Real condensation has now commenced and the obscurity changes from that of haze to that of mist. The whole process of

the formation of haze and mist is continuous, but they are fundamentally different, for haze owes its origin to foreign matter and the small amount of water associated with hygroscopic nuclei, while mist is due to an actual precipitation of water from vapor to liquid.

Fog

There is no fundamental difference between mist and fog: in most cases fog is only a dense mist, and the density at which mist becomes fog is a matter of definition. It is now the practice of the London Meteorological Office to limit fog to the obscurity in which objects at 1 kilometer are not visible.

When mist and fog are formed in fairly clear air they are white. On the other hand, if the air contains a large quantity of impurities, such as carbon particles from imperfect combustion, the mist particles absorb the impurities and become themselves dark-colored. In this way are formed those dense fogs in London which are likened to pea soup. It was originally thought that the density of a London fog was due to the fact that the smoke of the city provided an unusually large number of nuclei on which condensation could take place, thus offering a temptation to the air to deposit its moisture which it could not resist. As a matter of fact, there are always sufficient nuclei in the purest air in England to allow of the formation of fog whenever the meteorological conditions are suitable.

The relationship between smoke and fog is peculiar, and may be said to be accidental. The meteorological conditions which are necessary for the formation of fog are such that while they last, smoke can not get away either vertically or horizontally from the place of its origin. Thus during a fog practically all the smoke which London makes is kept over it and within a few hundred feet of the ground. This smoke, combined with the deposited water, can, as we all know, produce such an obscurity that midday is as dark as midnight. The total abolition of smoke from London would not reduce the occasions on which mist and fog occur, but many fogs would remain mists, and we should never have a "London particular." The fogs of London are caused almost entirely by loss of heat from the lower layers of the atmosphere into a clear sky above. The air radiates its heat, its temperature falls, and condensation takes place. Other methods of fog formation, such as the mixing of warm and cold air, are of secondary importance and never give rise to more than patchy local mists or light fogs.

Clouds

When air not saturated rises in the atmosphere its temperature is reduced by about 1° C. for every 100 meters of ascent. When

the ascent is carried far enough the dew point is reached, after which any further rise will cause condensation on the nuclei present. As the ascent is carried beyond the point of condensation more and more water is deposited, with a consequent increase in the size of the drops. This is the manner in which clouds are formed, and there are very good reasons for saying that it is the only way. Thus there is a fundamental difference between the method of formation of clouds and fogs: fogs form without any ascent of the air, while clouds are never formed without it. Thus it is not correct to describe clouds as fogs of the upper atmosphere.

The very sharp line of demarcation between the air under a cloud and the cloud itself needs explanation. The hygroscopic nuclei collect more and more water around them as they rise with the ascending current, owing to the increase in relative humidity. But when saturation is reached they are still very small, and produce little obscurity in the air. Such drops, however, need only 1 per cent. supersaturation to grow. Moreover, they are unstable, for as they grow they need less supersaturation. Thus, as soon as the air is sufficiently supersaturated to be in equilibrium with the nuclei, the slightest further rise causes the drops to grow very rapidly to the size in which they are in equilibrium with saturated air. The height at which this change occurs is the height of the base of the cloud.

Rain

When bodies fall through a resisting medium, such as air, they more or less quickly reach such a velocity that the resistance of the air equals the pull of gravity, after which they fall with a constant velocity, which is different according to the density and shape of the falling bodies.

Experiments have been made to determine the rate of fall of water drops through air at atmospheric pressure, and they show that the small drops in clouds would fall only at the rate of a little over a centimeter a second. As the drops get larger the rate of fall tends to a constant value of about 8 meters a second, while drops half a centimeter in diameter have the most rapid fall. Larger drops fall more slowly; for instead of retaining the shape of spheres they became flattened out, thus presenting an increased resistance to the air through which they are falling. When the size of the drop is such that, if it were not flattened it would have a diameter of about half a centimeter, the drop becomes very unstable, and all drops larger than this quickly break up into a number of smaller drops, which of course fall more slowly. This means that raindrops can never fall through air at a greater velocity than 8 meters

a second. Small drops fall slower than this, and large drops flatten out as soon as they are falling at 8 meters a second, and then soon break up into smaller drops.

W. H. Dines has found that in Europe the quantity of vapor in air is always very small. If the whole water vapor in the atmosphere on an average summer day were precipitated it would only give a total rainfall of 0.80 in. The greatest amount ever measured on a summer day in Europe would only give 1.5 in. of rain, and, of course, the quantity is much less in winter. Rainfall of several inches of rain in the course of an hour or so such as occurs in the tropics is due to ascending currents which carry with them their own water vapor to supply the rainfall. Ascending currents up to many meters a second are possible, and do occur in the atmosphere. Let us think of air rising at about 10 cm per second, which is the order of the upward velocity of the air in depressions. At a certain height cloud particles form as already described. These have a radius of about 0.001 cm and fall relatively to the air at 1.3 cm per sec.; hence they are carried upwards with the air, but the base of the cloud remains at the same height because new cloud particles are constantly being formed at that height. As the air rises the cloud particles grow in size, because water is being condensed on them, and they lag more and more behind the air. Drops with a radius of 0.002 cm are falling as rapidly as the air is rising, and therefore remain stationary, while drops of 0.007 cm are falling at the rate of 1 meter a second, and therefore fall through the rising air and appear at the earth's surface as rain. This process will continue so long as the ascending currents continue, and in this way we get the continuous steady rain with which we are so familiar in this country.

When the upward velocity of the ascending air becomes greater than 8 meters a second, no water can fall through the ascending air for the reason already explained. All water condensed in such an upward current—and it will be a very large amount—is carried upwards until the upward air velocity falls below 8 meters a second, as it is bound to do at some height owing to lateral spreading out. Here water accumulates in large amounts. It is the sudden cessation of the upward velocity in such an ascending current which gives rise to the so-called cloud-bursts; for when the sustaining current stops, the accumulated water falls just as though the cloud had literally burst.

The accumulated water while it is suspended in the air is constantly going through the process of coalescing into large drops, which at once become deformed and broken up again into small drops. Every time a drop breaks there is a separation of elec-

tricity, and this is probably the chief source of electricity in a thunderstorm. This explains why thunderstorms are associated with heavy rainfall and do not occur in polar regions, where there is no rain.

HAIL

Let us consider a region in the atmosphere through which there is an ascending current of air. The air is supposed to have a temperature of 20° C., and a relative humidity of about 50 per cent. at the ground. As the air rises, at first its temperature is reduced by 1° C. for each 100 meters of ascent. Hence by the time it has risen 1,000 meters its temperature will have been reduced to 10° C., and it will have reached its dew point. Here the cloud level begins. As it rises still further its temperature continues to decrease, but not so rapidly as before, because the condensation of water vapor releases the latent heat of vaporization. It reaches 0° C. at a height of 3,000 meters. Hence the region between 1,000 and 3,000 meters contains only drops of water. As the air rises above 3,000 meters the temperature falls still lower, but the water particles do not freeze at once, they remain super-cooled. We may assume that at −20° C., which is reached at about 6,000 meters, the super-cooled drops solidify and the remaining part of the cloud above this level is composed of snow alone.

There will not be a sharp division between the region of super-cooled water and the region of snow. For a certain distance ice crystals and super-cooled water will be mixed together. Such conditions are very unstable, the ice particles grow rapidly, and, if the ascending current is not too large, they will commence to fall. It has, however, to fall through 3,000 meters of super-cooled water drops, and in doing so grows appreciably in size. As each super-cooled water particle strikes the ice it solidifies, and also imprisons a certain amount of air, so that by the time the ice particle reaches the bottom of the super-cooled region, it is simply a ball of soft white ice.

If the descent through the super-cooled region has been fairly rapid, the temperature of the ice ball will be considerably below the freezing point when it arrives in the region where the temperature is 0° C., and the cloud particles are not super-cooled. As it continues its way downwards it receives a considerable addition of water: in the first place by direct deposition, because it is colder than the air; and, secondly, by collision with the water particles. This water covers the surface of the cold ice ball with a uniform layer of liquid which quickly freezes into clear solid ice, with little or no imprisoned air. Finally, the ice escapes from the bottom of the cloud, and falls to the ground as a hailstone.

When hailstones are split open to show their internal structure, we can nearly always see the inner soft white mass of ice which was collected while the stones were in the super-cooled region, surrounded by a layer of clear transparent ice formed by the freezing of the water deposited when the stone was passing through the non-super-cooled region.

Hailstones are formed only during thunderstorms, when violent ascending currents of air occur. Thus, while the hailstone is growing in size, its rate of fall may well be less than the upward velocity of the air. All the time, however, it will be moving relatively to the air, and its effective height of fall will be great. This would enable it to collect water, and so would account for the large size often attained by hailstones. Moreover, such an ascending current is not steady. Just as there are gusts and lulls in horizontal winds, so there are increases and decreases in the velocity of ascending currents. Thus a hailstone which has penetrated into the lower part of the cloud might be blown upwards and so go through the whole process again. In this case we should have a layer of white ice deposited around the clear layer, around which again there would be another layer of clear ice. This process might be repeated indefinitely, giving several concentric layers of clear and white ice, and a broken stone would have the appearance of an onion. Such cases are not at all uncommon.

For the formation of hailstones two conditions must be fulfilled:

(*a*) The clouds must extend through a great vertical height so that the three regions of water particles, super-cooled particles and snow are extensive and well developed.

(*b*) There must be violent ascending currents, otherwise the stones would fall too rapidly to grow to a large size.

These conditions are best fulfilled in warm regions, for there violent ascending currents are most easily developed, and the condensation starts at a relatively high temperature, so giving regions of water particles and super-cooled water particles of great depth. These are the reasons why hailstones only occur during the summer in temperate regions, and why the most violent hailstorms and the largest hailstones are found in tropical regions.

Soft Hail

The hailstone receives its coat of clear transparent ice in the region between the bottom of the cloud layer and the zero isothermal. If this region is much reduced, as when the temperature at the ground is low, the hailstones are relatively small, and consist only of the soft white balls appearing in the center of the more complete hailstones. Falls of soft hail of this nature are quite common in the winter in Europe. The temperature of the ascend-

ing current is so low that the freezing point is reached almost at the bottom of the cloud, so the hail falls almost immediately out of the region of super-cooled water particles, and has no opportunity for building up a layer of transparent ice.

Snow

Snow which forms over an ascending air current in which water particles first form will probably have solidified cloud particles for nuclei. Whatever the nuclei may be, as soon as the initial crystals are formed further condensation takes place exactly as in the precipitation of water, but the vapor condenses directly into the solid state without first going through the liquid state. The crystals of water are hexagonal prisms. Having once started, the crystals may grow either along their central axis, giving rise to long thin prisms, or along their six axes to form hexagonal plates, showing all the wonderful shapes that this form of crystallization can take.

In cold regions the crystals are small, because there is little water vapor present from which they can grow. In the Antarctic during the winter, when the temperature was always near or below 0° F., only the smallest crystals were seen, so small that they were almost like dust.

When crystals form at temperatures near the freezing point they grow to their largest size. When the air is full of large crystals frequent collisions take place. The crystals become interlocked and bundles of many separate crystals are formed; these produce the ordinary snowflakes which, on account of their size and weight, fall relatively rapidly. It is to these latter that the term snow should be applied.

WEATHER FORECASTING

By Lieutenant-Colonel E. GOLD, D.Sc., F.R.S.

This note treats only of weather forecasts for relatively short periods and leaves entirely aside forecasts of the character of seasons or years. Broadly speaking, there are three processes which a weather forecaster must take into account in his prediction.

(*a*) The travel of weather from one place or region to another.

(*b*) The development of weather in moving air.

(*c*) The development of weather at a place or in an area consequent upon orographical features, such as hills or coast-lines.

Hills may produce cloud and rain; they may get snow when lowlands get rain; they may be in fog when the lowlands are clear; they may get gales when the lowlands get only fresh winds. At the

coast, temperature may be low in summer when it is very hot inland, or mild in winter when there is frost inland; there may be fog in summer when it is clear inland, or thunderstorms in winter when there are none inland. The coast-line is also a line of discontinuity so far as the resistance to atmospheric motion is concerned, and on that account it modifies the normal development of a cyclone.

The meteorologist at a central institution is better situated for dealing with the problems presented by (*a*) and (*b*) than a meteorologist at a local sub-office; but the latter has a very definite advantage in regard to (*c*) so far as the locality in which he is situated is concerned.

The idea underlying the method by which the problem of forecasting has been attacked is that the problem is one of mathematical physics, and that if we knew exactly what the physical condition of the atmosphere is at a given instant we could, theoretically at least, deduce what the conditions would be at subsequent times. Accordingly as much information about the weather existing at a given instant at different places over as wide an area as possible is collected rapidly at a central institute.

The actual problem can not be solved in exact mathematical fashion; but its explicit formulation and the application in present-day forecasting of the general mathematical and physical principles involved in the solution of the idealized problem do mark a definite advance beyond the pure empiricism of the earlier forecasters.

The organization in Europe by which the collection of information is made has grown rapidly since the war. In each country the observations from a selection of stations are issued by wireless telegraphy according to a prearranged time-table; these issues are received at the Air Ministry, and the observations are plotted on maps to enable the forecaster to get a rapid view of the existing situation. This is done three times daily (7 A. M., 1 P. M. and 6 P. M. Greenwich time), and a smaller collection of information is also made in the night (1 A. M. Greenwich time). The information from each observing station includes pressure (barometer); temperature; humidity; direction and force of the wind; existing weather and general character of the weather since the preceding report; form, amount and approximate height of cloud; visibility or distance at which objects can be seen; and the manner in which the barometer has been changing in the preceding three hours.

Early Forecasting

The dominant idea in British forecasting used to be the travel of weather, and efforts were mainly directed to discovering how the path of weather could be foretold. It was found from the earliest

studies of synoptic weather charts, some fifty years ago, that the two outstanding features were cyclones or regions of low barometer, and anti-cyclones or regions of high barometer. Broadly, the first were associated with windy and wet weather, and the second with quiet dry weather. If the coming of windy and wet weather can be forecasted correctly, then, *ipso facto,* quiet and dry weather can also be forecasted. It seemed therefore fundamental to understand the distribution of wind and weather in the area of a cyclone, and this was formulated by Abercromby some forty years ago in a generalized way. Upon this and the analysis by van Bebber of the paths of depressions at different seasons, forecasts were mainly based. A cyclone was indicated by readings of the barometer, its path and speed of translation were estimated, and the sequence of weather to be expected at any place could then be written down more or less accurately.

It was indeed recognized that deformation of the cyclone might occur, and that a bulge of the isobars, usually at the southern extremity, might have the features of wind and weather appropriate to a cyclonic entity without necessarily having the closed isobars, although in some cases it might have them, too. Such bulges came to be called secondaries. It was also recognized that cyclones differed considerably among themselves in regard to the actual distribution of weather, but there was no satisfactory physical explanation of the variations: they could only be forecasted for a region to which the cyclone was moving, when their existence was indicated in the actual reports from the region where the cyclone was then situated.

The manner in which the barometer changed was always recognized to be of importance, but it was not until the introduction of relatively cheap self-recording aneroid barometers (barographs) that the significance of these changes was more fully appreciated. The first great step forward in modern forecasting since 1885 came in 1908 with the introduction into the reports from observing stations of a precise indication of the character and rate of change of the barometer. From that time the forecaster knew, not merely if the barometer was rising or falling, but also the rate at which it was rising or falling; he also knew the character of the curve of variation for the preceding three hours; he knew, for example, if the barometer had been steady and had commenced to fall, or if it had been falling continuously, or if it had been falling and had commenced to rise.

This information facilitated considerably the task of estimating the travel of weather, but it contributed also to the solution of problem (*b*) and made the prevision of the development of secondaries

more certain; or, what is, perhaps, a more important point, it enabled longer warning of these developments to be given. Still it was mainly from the point of view of the "travel" of weather that this and other improvements were effected and only a little light was thrown on development.

Significance of Cloud Movements

Another advance was made about the same time when it was proved that the direction and speed of the wind at heights between about two thousand feet and five thousand feet could be found very simply from the charts of isobars with practically the same degree of accuracy as that reached by wind-measuring instruments. It had been proved that if the motion of the air were "steady" this would be the case; but it was not until the present writer verified in 1907 the agreement of the hypothetical values with actual records at heights of one thousand five hundred feet and three thousand feet, that it was imagined that the motion could be steady enough for the calculation to be of practical value.

This result has applications in the whole field of practical meteorology. Its bearing on forecasting may be seen by considering that clouds travel and are most important features of weather, and that a means of knowing the direction and speed of the air at heights comparable with those of clouds permits of greater precision in regard to the time at which weather changes will arrive at a place.

A further step forward was made when observations of temperature at different altitudes came to be available in time for use by the forecaster. Such observations are essential to a proper understanding of the general meteorological situation; they are especially valuable in connection with the problem of "development" (*b*). Their usefulness in two special directions may be illustrated as follows:

(*a*) The temperature of the upper air practically sets an effective limit to the maximum temperature which can be reached at the ground in the daytime. If, for example, the temperature at five thousand feet is 25° F., then the temperature at the surface can not rise above 55° F., as a result of a day's sunshine; and if the air is damp as well as cold, the temperature at the surface will not rise above 45° F.

(*b*) A high temperature in the upper air limits the development of vertical motion and the consequent production of cloud. If, for example, the temperature at ten thousand feet is 50° F., and decreases only slowly at higher levels, then there can be no development of cloud above the ten thousand feet level unless the surface

temperature rises above 85° F.; if the temperature at five thousand feet is also 50° F., then the surface temperature can not rise above 80° F., and it is impossible to get the thick cumulo-nimbus clouds of thundery weather without the influx of entirely different air.

One of the most recent developments, a contribution from France, is essentially an extension of the principles enunciated by Abercromby. The atmosphere, at least in temperate latitudes, may be divided into regions of cloudless weather and regions of cloud. A region of cloud consists of a central core of thick cloud and wet weather; in passing from the core to the fine weather area, the cloud experienced depends upon the direction in which the transition is made.

In front of the "core," on the outer edge of the cloud region, are cirrus clouds (mare's tails); nearer the "core" these are replaced by cirro-stratus or a veil of whitish cloud covering the whole of the sky; just in front of the rain area is alto-stratus or a thick veil of grey cloud. On either side of the "core" are cirrus and cirro-cumulus (mackerel sky) or alto-cumulus. Behind the "core" are again occasionally cirrus clouds, but generally alto-cumulus and cumulo-nimbus (thunder cloud), giving showers or thunder-showers

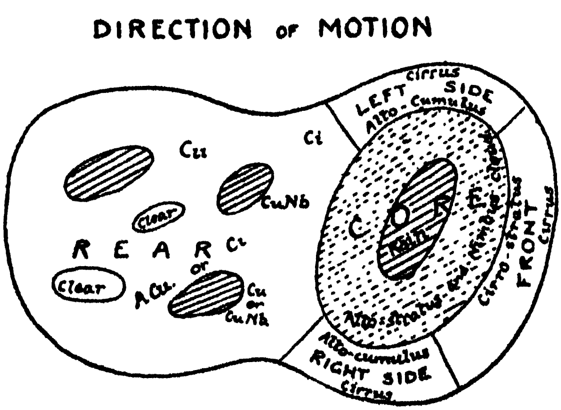

Fig. 1. Cloud Regions

and bright intervals. The diagram, Fig. 1, is a rough illustration of a cloud region as conceived in the French system. Actually there are, in individual cases, many divergences from this generalized representation.

The "core" is the dominating feature and, once it has been identified and its limits observed, forecasting becomes a simple matter, if, as the French believe, the motion of the "core" is not attended with the uncertainty of the motion of the center of a depression, but is practically identical with the speed and direction of the

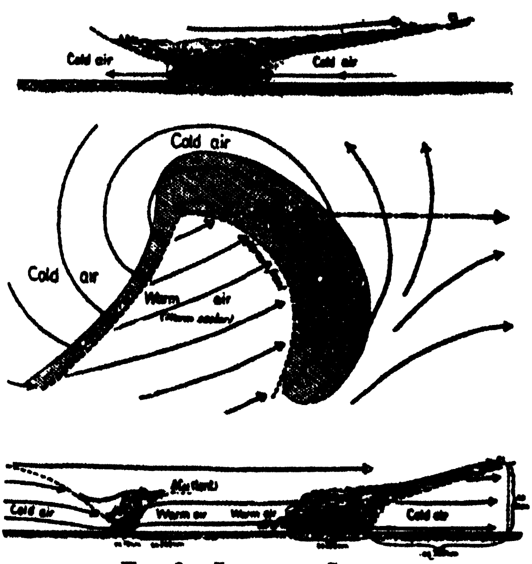

FIG. 2. IDEALIZED CYCLONE

wind at about ten thousand feet. The "core" may be associated with a cyclonic depression, but it may also arise wherever there is a tendency for the formation of a secondary—*i.e.*, wherever there is an area over which the change of the barometer relative to the change in surrounding regions is generally downwards.

THE THEORY OF THE POLAR FRONT

Undoubtedly the greatest recent advance is that associated with the name of V. Bjerknes. Like a poet, he has turned to shape the ideas, latent in the minds of forecasters and physicists, or suggested tentatively, as in Sir Napier Shaw's diagram of the constituent parts of a cyclone, in which he shows a cold east current, a cool or cold west current, and a warm south current, as making up a cyclone.

Bjerknes' theory is briefly as follows:

The polar regions are covered by a mass of cold air, and the tropical regions by a mass of warm air. There is not a continuous change from the cold air to the warm air, but the two masses are separated by a surface of discontinuity—the *polar front*. Cyclones develop at this surface of discontinuity and constitute the mechanism by which interchange takes place between the cold air and the warm air. Each cyclone consists of two sectors, a warm sector of tropical air and a cold sector of polar air. The warm air pushes the cold air in front of it, and at the same time rises over the cold air; the cold air behind the warm sector pushes underneath the warm air, so that normally the warm sector is being reduced in area and is lifted upwards.

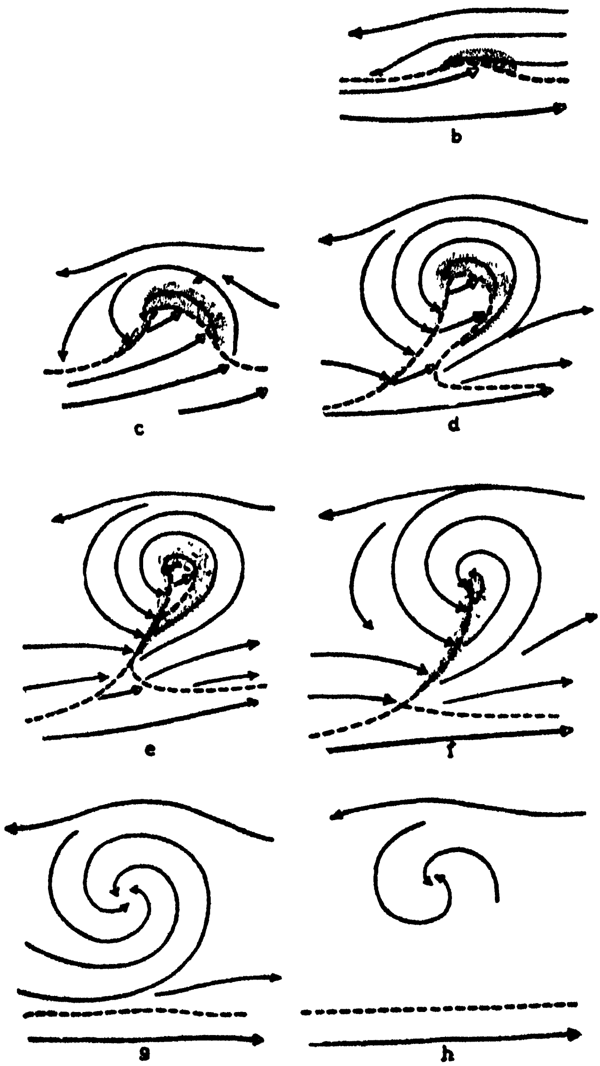

FIG. 3. LIFE CYCLE OF A CYCLONE

In the inner area of a cyclone, the cold air may, and often does, get right round, with the result that the warm sector is cut in two. The cyclone itself then begins to diminish in intensity. The result is a transposition of the polar front and a new cyclone or secondary usually forms with the remainder of the warm sector and the transposed polar air as its constituents.

The diagram, Fig. 2,[1] illustrates the structure of a cyclone. The shaded part is the area of rain (or snow), and the sections at the

[1] Figs. 2, 3 and 4 are reproduced from a paper by J. Bjerknes and H. Solberg, entitled "Life cycle of cyclones and the polar front theory of atmospheric circulation."

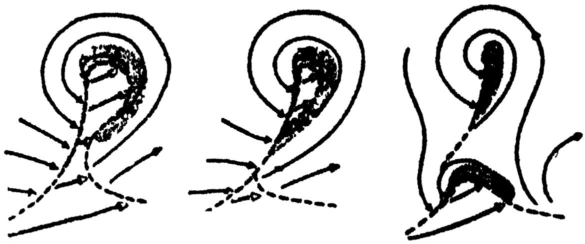

FIG. 4. FORMATION OF A SECONDARY CYCLONE SIMULTANEOUSLY WITH THE SECLUSION OF THE "MOTHER CYCLONE"

top and bottom of the diagram are vertical sections through the cyclone to the left and right, respectively, of the path at the center.

The normal birth, life and death of a cyclone are illustrated in Fig. 3. It shows a cold easterly current and a warm westerly current in juxtaposition. The cold air begins to bulge southwards, and the warm air northwards in (*b*). In (*c*) a cyclone has formed, and (*d*), (*e*), (*f*) show successive stages, until the whole of the warm air has been lifted above the cold air. The cyclone gradually dissipates, as indicated in (*g*) and (*h*).

In Fig. 4 the formation of a secondary is shown. The cold air in front of the line of discontinuity can not move away quickly enough; it gets dammed up, and some of it begins to flow backwards and so produces the conditions requisite for the development of cyclones.

In its broad features the theory of Bjerknes is in accordance with the facts of observation and the laws of physics. Further investigations of the upper air will elucidate some points of difficulty and will possibly necessitate modification in details. The outstanding advantage of the theory is the light which it throws on "development." By its aid the forecaster can now see how an existing cyclone will develop; whether it will go on increasing in intensity, or if it will become stationary and fill up; he can also see where a new cyclone is likely to develop *before any actual development has commenced.* Our knowledge of process (*b*), development of weather, is now nearly, if not quite, as good as our knowledge of process (*a*), the travel of weather. Bjerknes has acknowledged his debt to previous investigators, notably Margules and Sir Napier Shaw; but the glory of the architect's work is increased rather than diminished by the excellence of the bricks which others had made ready for the building.

PROSPERITY AND POWER

By Professor SUMNER B. ELY and Professor WALTER F. RITTMAN

CARNEGIE INSTITUTE OF TECHNOLOGY AND CONSULTING ENGINEERS TO THE PENNSYLVANIA GIANT POWER SURVEY

THERE have been several articles written in the last few years giving estimates of the future growth of the population of the United States—what the saturation point is and how long it will take to reach it. These articles have generally assumed that various checks will hinder this growth. In most cases the food supply has been taken as the only limiting factor; but none of them seemed to consider that our industrial prosperity depends on power generated in the community and that this phase of the question must not be neglected.

Of course, if we are to consider that the United States is in the same class as China or India, then perhaps the doctrine of Malthus can be applied and everything put on the basis of food supply; and it is conceivable that some time in the future the population of the United States might have deteriorated to such a condition. But long before this is likely to happen the industrial prosperity of the United States would have gone, and so it is of great interest to know how long the industrialism of the United States can last.

There seems to be a prevalent idea in the minds of many persons that the great wealth of the United States is due to its farms; and the statement is often made that when we have bumper crops we have boom years. It is interesting to note the United States Census figures given in Table I, which indicate that the manufactures are several times the value of the farm products. The years 1919 and 1921 have been chosen for illustration, because, while there is considerable difference in the figures for the two years, yet they show the proportion between farm products and manufactures to vary but little. We are not concerned with intrinsic value and

TABLE I. VALUE OF THE FARM AND MANUFACTURED PRODUCTS OF THE UNITED STATES FOR THE YEARS 1919 AND 1921

Farm Products	1919	1921
Value of crops produced	\$15,400,000,000	\$6,930,000,000
Value of live stock products	8,360,000,000	5,468,000,000
	\$23,760,000,000	\$12,398,000,000
Manufactures		
Finished value	\$62,418,000,000	\$43,790,000,000

there may be some difference of opinion as to the exact interpretation to be put on these figures; but they show beyond a doubt that our material prosperity is dependent in large measure on our manufactures. Our manufactures in turn are dependent on our ability to generate power, and if the United States is to go on increasing in population and at the same time maintain its prosperity, then power must increase and develop with the population.

The Giant Power Survey definitely indicated the trend of development in manufacture to-day. For the production of power both fuel and water are necessary. In the past each manufacturing establishment generated its own power within its own walls; and if this is to continue, as the country becomes more and more settled, it will involve an increase in railroad facilities for handling fuel; but what is much more important it would be but a comparatively short time until all the available water sites were occupied. A location at a coal mine mouth is less important than the water site, because fuel can be brought to a plant. In other words, water seems to be the limiting factor rather than fuel.

Fortunately the solution for these difficulties is at hand, now that the electric wire has displaced the belt. Power is now transmitted to almost any distance and the manufacturer can locate his plant independently of power-generating conditions. The possible size of the central electric generating power plant, located strategically as to coal and water supply, is nearly unlimited; and it can sell power to the manufacturer cheaper than he can generate it. Fig. 1 shows how purchased electric power is displacing individual

THE RISE OF ELECTRIC POWER IN PENNSYLVANIA
MANUFACTURING AND MINING INDUSTRIES

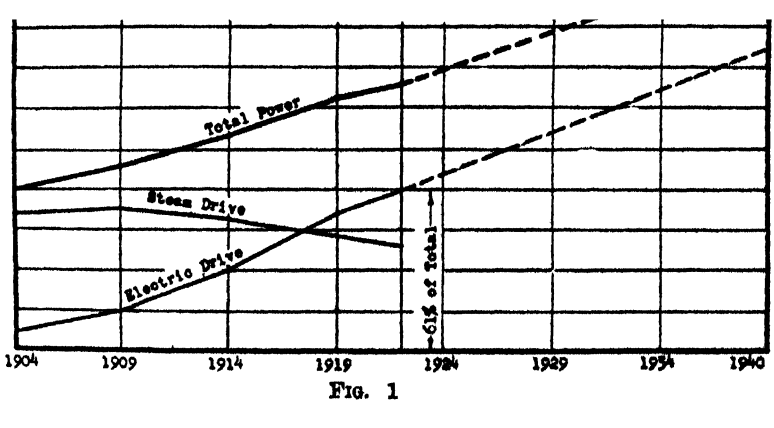

FIG. 1

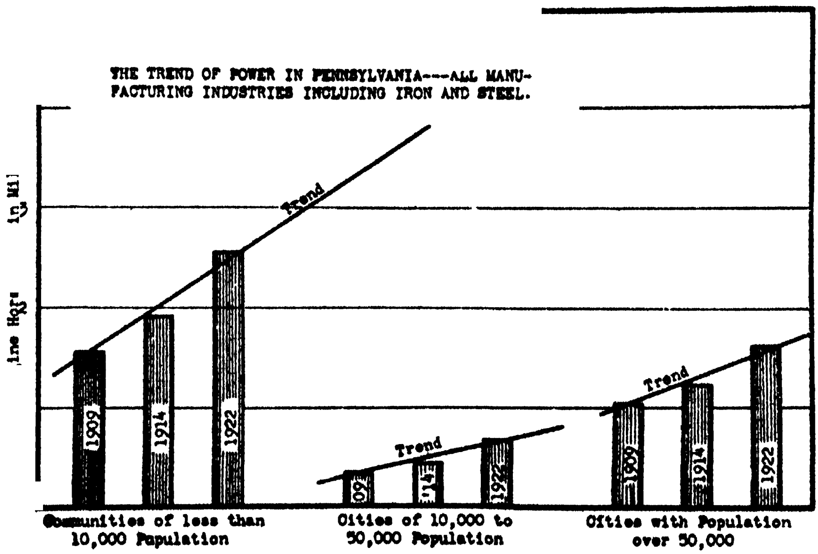

FIG. 2

power generation in the industries of Pennsylvania. In other words, power in manufacturing is becoming as much of a commodity to buy and sell as raw material.

Fig. 2, reproduced from the Giant Power Survey Report, shows that manufactures are already moving away from congested centers. This chart was made by dividing the cities of Pennsylvania into three groups and plotting, first, the sum of all the manufacturing power in cities having over 50,000 population; second, the sum of the manufacturing power in all cities from 10,000 to 50,000 population; and, third, the manufacturing power in small towns and areas outside corporate limits.

It will be noticed how much steeper the line for the communities of less than 10,000 population is. These facts afford a striking illustration of how much faster the power consumption is increasing in small communities, as contrasted with the big city. A map of the state of Pennsylvania, having plotted on it the density of industrial power in each county, will show large areas in the central portion of the state where there is little or no manufacturing. Now, however, that power from large interconnected electric stations is becoming available, these areas are beginning to develop industries; and it is thus possible for the number of Pennsylvania's manufacturing plants to increase to a tremendous extent.

Therefore, as the installations of power stations increase throughout the United States, the country will tend to become a network of wires; and should this happen, industrial plants and

manufactures could increase almost without limit. It becomes, then, a very interesting question as to where all this power could come from and how long it could be maintained.

The first power that man used was undoubtedly his own strength. It has been estimated that the average man is capable of doing 3,500 foot pounds of work per minute and that he can maintain this rate of work for eight hours. On this basis it would take the enormous number of 2,274,000 men to do the same work as one of our 60,000 kilowatt steam turbine units running continuously. When we think of the small space that this machine occupies, the absurdity of operating an industrial community on man power is evident; to say nothing of the many other objections.

The same is true of animal power. A picture has come down to us from the middle ages that shows a prodigious number of men and horses gathered together in a large field to perform some such work as raising a large monolith. To make these men and animals work effectively together must have been a very difficult undertaking. Contrast this with the Liberty motor built during the war for aeroplane service. This motor is rated at 400 horse-power and occupies about the same space as one horse. Its work output is under the most perfect control.

Wave power, tide power, wind power and sun power can all be put in the same class. They have all been tried and all proved unsuccessful. The chief reason is that the power is too diffuse. It would take an enormous platform riding on the waves to generate even a small horse-power. Large greenhouse-like structures have been built to gather the sun's rays; but the power obtained was very small for the very large outlay. Parabolic mirrors have been placed around a boiler, but have been unable to raise steam, much if any, above atmospheric pressure. It is true that by the use of proper condensing apparatus some power could be obtained; but to develop, by this means, the enormous horse-powers needed to-day is out of the question. Since the days of Archimedes various devices have been tried to utilize these forms of energy, but they are totally inadequate and far too uncertain for industrial purposes.

Late investigation seems to indicate that volcanoes, hot springs, etc., are local, and that the internal heat of the earth may be a myth. If it exists, perhaps some day we can tap it; but at present we must realize that water-falls and fuel are our only two real sources of power. The greatest part of the sun's energy coming to the earth is consumed in heating the atmosphere and in evaporating water. A small part of this is recovered from the rain of clouds falling on high ground and the energy of flowing water results; and

hence our water power. That portion of the sun's energy that goes into vegetation has some power possibilities, for wood and other vegetable matter make good fuel. Our wood supply, however, is being used up some five times faster than it is being replenished by new growths. Possibly certain plants might be grown each year from which oil can be extracted which could be used as fuel. However, our real source of supply is that portion of the sun's energy that went into vegetation in ages past and is now locked up in the form of coal.

Let us consider the water power possibilities first. The United States Geological Survey estimates that the potential water power resources of the United States are about 55,000,000 horse-power, available 50 per cent. of the time; of this only about one fifth has so far been developed. From these figures, if the water power were all developed, it would produce 242 billion horse-power hours per year

The actual requirements of the country are given in Table II for the year 1922. The industrial figures of the table were obtained by applying the known load factor of Pennsylvania to the installed horse-power of the United States. The railroad horse-power hours

TABLE II. THE HORSE-POWER HOURS DEVELOPED IN THE UNITED STATES IN 1922

Manufacturing and mining, including electric power purchased	86	billion	horse-power	hours
Electric power stations, excluding that sold to industry	20	"	"	"
Railroads	45	"	"	"
Automobiles	27	"	"	"
Navigation and miscellaneous	80	"	"	"
Total	258	"	"	"

have been estimated from a knowledge of the coal used by the railroads in 1922, and the automobile figure from the gasoline consumption. The navigation and miscellaneous figure is based partly on registered tonnage; but it is rather loose, for it is difficult to say what proportion of our ships' fuel should be charged to the United States. However, the figure seems to check out from other points of view, and it is close enough for our purpose.

Comparing now the two final figures, it will be seen that with all our water power developed, it would hardly have met the demand in 1922. If now Fig. 3 is looked at it will be seen that if our industries maintain their present rate of growth, they will have doubled by 1950. Our power requirements would seem to be doubling every

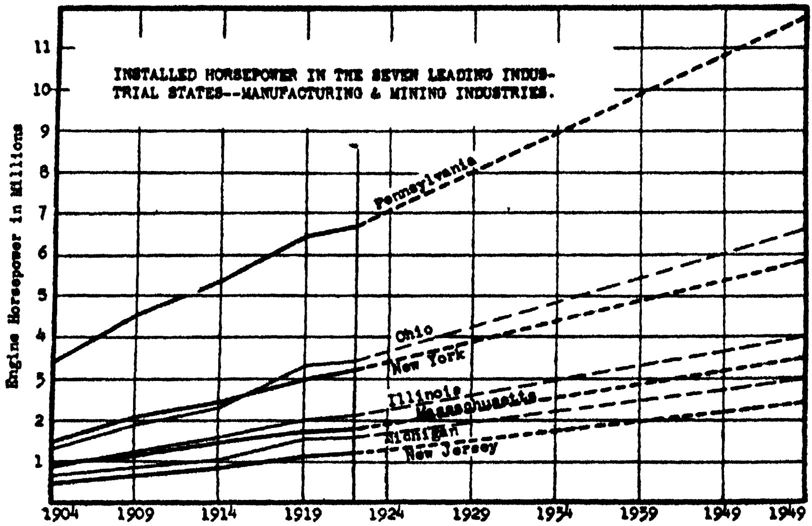

FIG. 3

twenty-five years. How long this will keep up is only conjecture; but the fact that the electric power industry itself is doubling every five years, and that Giant Power and Superpower are becoming facts, would lead one to believe that if the other necessary factors develop at the same time, we may be entering an era of development that will be greater than anything ever yet known.

However this may be, it seems certain that although water power may carry some of our load, our real dependence must be placed on our fuel reserves. And fuel reserves mean coal reserves. Natural gas is practically exhausted. Our oil can not last much longer, and this will probably make a further demand on the coal, as our gasoline of the future is likely to come from coal distillation earlier than from shales. Furthermore, while we have been considering coal from a power generation point of view only, in reality a large portion of the coal mined is used for industrial heating and other processes; so from every standpoint it becomes of increasing interest to know how long our coal reserves are likely to last.

In the state of Pennsylvania we know with considerable accuracy how much coal is still in the ground. The whole state has been carefully mapped and measured by the State Bureau of Topographic and Geological Survey. Table III contains their bituminous coal figures. Anthracite coal deposits we have not considered; they are comparatively small and used mostly for domestic purposes. The figures given in Table III for the original deposits include all veins, whether minable or not, while in the estimate of recoverable coal only veins that are thicker than 18 inches are in-

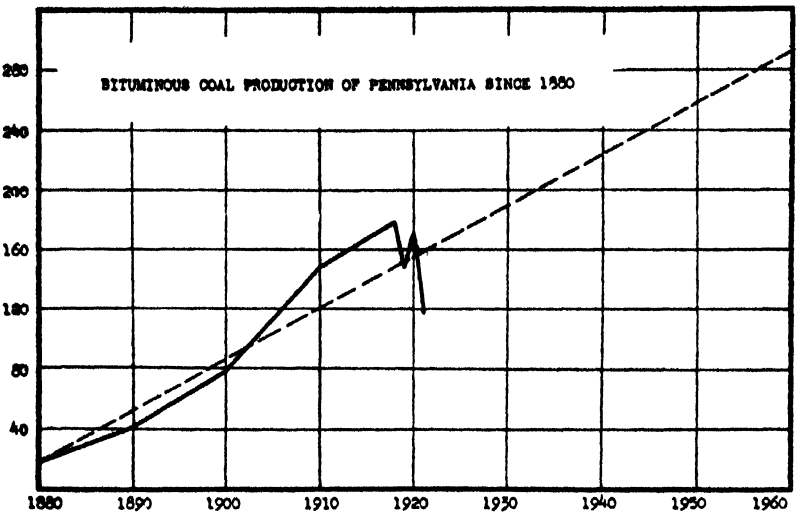

FIG. 4

TABLE III. THE BITUMINOUS COAL OF PENNSYLVANIA

Original Deposits	Mined Out	Recoverable
75,259,055,000	5,519,665,000	43,830,860,000

All figures are in short tons

cluded, which accounts for the difference very largely in the size of these two figures. There is no lignite or sub-bituminous coal in Pennsylvania and all the 43 billion tons of reserve are good usable coal.

Fig. 4 is a plot of the bituminous coal mined in Pennsylvania since 1880. Assuming that the increase of coal mined in the past, as shown by the curve, will be continued, the dotted line has been projected into the future. Equating the area under this line to the 43 billion tons coal reserves, it will be found that these reserves will be exhausted in 118 years. If, instead of considering a yearly increase, the assumption is made that the coal mined each year will be the same from now on, then it will be found that the 43 billion tons will last about 250 years. The true figure probably lies somewhere between these two extremes. This means that the end of Pennsylvania's coal is in sight.

This same method can be applied to the coal resources of the United States, but with very much less accuracy. In 1913 an International Geological Congress was held in Canada, the result of which was the publication of three volumes giving the estimated coal reserves of the world. This was a wonderful piece of work and the records are of the greatest value, but the same degree of accuracy can not be expected, as in the Pennsylvania estimate where each square foot of ground was laid out on a drafting board and

planimetered. The coal in our western states is by no means as well known as that of Pennsylvania. Then, too, the figures given for recoverable coal include all seams down to 12 inches thick, while the Pennsylvania figures do not include anything less than 18 inches thick.

For these and other reasons the method of calculation used for Pennsylvania is not satisfactory when applied to the United States. Such figures as we find, however, lead to the belief that in a very few hundred years all our best coal will have been exhausted; the zenith of industrial prosperity will have been reached and from then on a gradual slowing down of production will take place.

In Table IV is given the distribution of the world's coal reserves as determined by the Geological Congress. As North America has

TABLE IV. DISTRIBUTION OF THE WORLD'S COAL RESERVES

North America	68.7	per	cent.
Asia	17.3	"	"
Europe	10.5	"	"
Australia	2.3	"	"
Africa	.8	"	"
South America	.4	"	"
	100.0	"	"

nearly 70 per cent. of the coal of the world, it must be looked to very largely to keep the world going and what has been said about the United States can probably be said about the world generally.

Whatever interpretation we choose to put on such figures, we certainly must realize the rate at which our resources are going. For countless ages man has lived on this earth with the coal practically untouched, then suddenly, less than a hundred and fifty years ago, the industrial age began, with the invention of machine tools and the steam engine, and in that short period this enormous consumption of coal has taken place. Our fuel-saving refinements will help, but they seem like a drop in the bucket in the face of the ever-increasing demand. As Fred R. Low, president of the American Society of Mechanical Engineers, has well said: "It is a good thing for us that the industrial age did not start in the time of Tutankhamen, or to-day we would be fighting among ourselves for the last few remaining heat units." And even if we care nothing about the future from an altruistic point of view and ask ourselves the question: "What has posterity ever done for us?" still it is interesting to wonder if 2,500 years from now the words "prosperity" and "civilization" will have taken on a very different meaning.

Our present outlook is that when the coal goes so will prosperity. Will science do anything for us before this happens? Will somebody some day discover how to make heat run up hill, so that we will need a new theory of thermodynamics; or will some one get control of the energy we believe to be in the atom? These are dreams. We have been living in a time when we have seen under our very eyes tremendous changes taking place in industrial life. The application of scientific principles has developed rapidly, and we have therefore come to believe that this rapid development will continue, and that sooner or later some source of energy, other than coal, will become available. Our attitude is one of waiting for something to turn up. Possibly a wiser and certainly a more practical attitude would be one of conserving our resources.

Perhaps true prosperity is not industrial prosperity at all, and that man was happier in the olden days. Man got along without power until just yesterday, so to speak, and most of mankind get along without it still. It may be that man is not as happy now as he was, but it surely can be said that wealth and comforts are widely distributed as never before; and whether we believe this industrial age with its great mass production is best for mankind or not, the handwriting on the wall says that it has come to stay and to increase.

Our civilization is one of industrial production, and this is the one difference between our civilization and the many civilizations that have preceded it and failed. Will our civilization endure? If it does, then power must endure.

THE PHYSICAL BASIS OF DISEASE

XI. MEDICINE OF THE FUTURE

By THE RESEARCH WORKER
STANFORD UNIVERSITY

"IT would be interesting to know the relation of theology to medicine a hundred years from now," said the manufacturer, as he wished the research worker and family Godspeed, at the railway station, a few evenings later.

That night the research worker tossed in a stuffy berth, a medley of dreams and half-waking thoughts, essence of a hundred sleepless nights. In his dreams he revisited California in the thirtieth century. Saw the old placer region, now a segregation district for industrial plants. The eugenic colony of the San Joaquin valley. The great state wineries of the Fresno region. The crime-prophylaxis station at Carmel.

"Yes," he murmured, wakened at a junction by returning college students, with their ever-varying parodies on Alexander's Ragtime Band, "it would take a Tamalpais."

Unable again to sleep, he dressed and jotted down his main impressions of Thirtieth Century California.

I found myself in the office of a great physician of the thirtieth century.

"My bill?" asked the patient.

"Two and a half wilsons," replied the physician.

"May I see those coins?" I asked.

"Gold and silver mixtures," the physician explained. "Named after Patrick Wilson, first President of the Nordic Union. No relation of the Wilson of your day."

"Nordic Union?"

"Founded, 2113, after the second Pan-Europasiatic War. Hundred fifty million killed. California invaded. Half a million women and children killed here. Here's the atlas. Nordic Union, red. Mediterranean, green. Asiatic, blue. African, buff."

"The value of a wilson?"

"Average daily living expense, one adult, Nordic Union. Relative proportion of gold and silver varied from time to time to stabilize its purchasing power. Size and design constant. Similar

units in other Unions. Mediterranean unit, twenty per cent. less gold. Asiatic, forty per cent."

"A handicap to business," I objected.

"Interunion transactions are mainly by bankers' credit. The four world units are equalized in world-purchasing power by import taxes or bonuses, equal to the difference in the gold content of the units involved. With a normal trade balance, the taxes and bonuses offset each other. Otherwise, world-wide free-trade."

"But the revenue of a country?"

"Mainly from state owned shares in public utilities. No state allowed to own more than 33 1/3 per cent."

3

The physician's office expanded to the dim-lit interior of a great Protestant Church. The choir swung into the familiar refrain. Trumpets dominated the orchestra. The standing congregation raised their right hands:

> I rejoice! I rejoice! In Divine biologic laws.
> I obey! I obey! Thy Divine biocommand.

Changing to the voice of a great historian in whose study I was sitting.

"The Biologic Reformation," he was saying, "dates from 2015, the Miracle of Mount Tamalpais. Here is the account. Third Testament, Second Chapter, Letters of St. O'Neill, reporter for a San Francisco paper, who won the Pulitzer prize for the best description:

> 5. And, on the third day, a Wondrous Light appeared over Tamalpais, increasing to a Brilliancy no eye could stand, a Light leaving no record on photographic plates.
>
> 6. And, from this Brilliancy, there materialized a Great Face, Countenance of Eternal Youth, over-topping the stars, visible to far distant Sierras.
>
> 7. The Lips opened, and, in a Voice each heard in his own tongue:
>
> 8. "I give unto you a new Command, the Biologic Law. From the anthropomorphic brute in whose body I created you, you have evolved a demi-deity. You have gained much dominion over external forces. WE are pleased. Now, say I unto you, gain you also dominion over your own biologic selves."
>
> 9. The Face dimmed, slowly disappeared. And those who would approach found Tamalpais denuded of vegetation, with heat so intense none could ascend.

The Bible shrank to a wine glass in the hand of a great industrial chemist.

"Not the rotting fruit and putrefying grain of your generation," he was saying, "but juices of freshly gathered fruits, mixed with other vegetable products. Freed from putrefactive microorganism by porcelain filtration. Aged. Aromatized. Carbonated. Vitaminized and neurhormized by ultraradiation. The inception of the process dates from your time, the early partial vitaminization of inert oils by ultraviolet rays. Wine is at present the largest industry in the state. A million employees."

"The labor?" I asked.

"Agriculture laborers, mainly Italiojapanese hybrids. Technical workers, largely Francoprussian blends."

"Hybrids! Blends!" I exclaimed. "Supervised marriage!"

"No. Public opinion discourages undesirable hybridization. Otherwise, the individual usually marries at puberty the mate of his choice."

"At puberty!"

"To be exact, during the nuptial sabbatical, first pubescent year."

"My own research field," he continued, the wall of the room disappearing, revealing his private laboratory. A topsy-turvy land. Inverted receptacles, up-side-down filters, fragments of broken apparatus floating near the ceiling. "Is aeriometallergy. Gravneutral, gravnegative alloys."

"Gravnegative physics," he explained, "dates from 2516, the discovery of differences in the gram-momenta of certain metals moving in vacuo. The first gravneutral subelectron was not isolated till nearly a hundred years later, however. The first gravnegative subatomocentrosome, not till two hundred years later. Our main commercial supply of negons is from subcentrosomal cracking."

"The chemistry of my day?" I asked.

"Ten centuries of the pseudo-chemistry scrapped, by the beginning of the modern era. This we date from 2781, the perfection of methods for electron and centrosome synthesis."

5

The chemist's voice changed to the natal wail of an infant in the hands of an obstetrician.

"Nordichebraic hybrid," he was saying. "Superior to the Nordicarabic and Nordicegyptian blends encouraged in England."

The resident hormonologist took up a hypodermic syringe.

"You had hormones in your day?" he asked.

"Insulin," I said.

"Crude initial product. Mixture," he replied. "This is gonstasin. Highly specific antimitosigen. Act solely on the attraction-sphere centrosomes of gonocytes. Enough bound to the centrosomes to delay gonocyte mitosis ten to fifteen years. Delays puberty. Females, till twenty-fifth year. Males, till thirtieth. Offset by postponed menopause and delayed senimpotence. Same length of time."

"The purpose?" I asked.

"Our natural reproductive period was well adapted to prehistoric man. Poorly adapted, however, to modern education, to modern life-expectation. Youth-prolongation is compulsory in the Nordic Union. All new-born. One of our most valuable eugenic and hygienic measures."

"Your life-expectation?" I asked.

"Increased rapidly during the first five decades after Tamalpais, with the resulting general application of known hygienic facts. Since then, advance has been slow, depending mainly upon laborious mastery of new facts. Our average life-expectation today is 67.4 years. Eventually, we hope to reach the three-score-and-ten of Biocommand."

"Not my understanding of the text," I objected.

"Careful retranslations, during the time of His Holiness Tamalpais I, show that this was the original meaning."

"The Chief has his neghenry on the roof," he added, "going to show you the senilorium."

6

"Looks familiar," I said, as I found myself seated in the well-known model.

"Yes," replied the hormonologist, "we've reproduced the external features of the historic car preserved in the Memorial Museum, at Henfrd. The surface henry and neghenry are the official Nordic Union insignia for physicians of the ford class. Perpetual tribute to that far-seeing man, who contributed a quarter of his fortune to founding the Research Institute for Molecular Physics, at Ann Arbor, from which came the discovery of rectangular ultraradiation-interference in radio-active crystals, basis of modern diagnosis."

The henry rose to the passenger level.

"Physician of the ford class?" I asked.

"On graduation, medical students are licensed as B-class physicians, entitling them to practice only under the supervision of a physician of higher rank. After five years, about two thirds of them are raised to the A-class, allowing independent practice. Ten

years later, about a quarter of the A's are raised to the consulting, or ford class, M.FD. Corresponding to the highest rank in other professions, Ph.FD., D.FD., etc. The fordate is required for responsible public health and teaching positions. Most research workers are fords, though some of the best work ———

"Oyez!! Oyez!! Oyez!" from an approaching air-liner.

"Emergency-ambulance call," said the hormonologist. "Grab th' straps!"

And the henry shot forward to the ground.

We reached the ground a few seconds before the slowly descending body. Its fall retarded, I was told later, by a gravnegative suit.

The body landed on its feet. ("God! It's Ford Jones!") Slowly collapsed to the ground. Fragments of viscera rained down from the slowing propeller, now overhead, a three-foot length of intestine sliding from a frond of an adjacent palm.

A hemostat plunged into the gaping abdomen. Jugular exposed. Thermos trocar inserted.

"Control the flow! Thirty cc per second."

Ruptured spleen, shreaded stomach, intestinal fragments, thrown to the ground. A dozen rapid hemostats. And the emergency-ambulance dived to the ground. Another thermos. And, disregarding all traffic regulations, the burdened ambulance sirened toward the hospital.

"Spectacular stunt!" I said. "But what was the use?"

"Oh! He'll be all right. Few weeks."

"Exsanguinated!" I objected. "Practically eviscerated! Stomach, intestines, spleen all gone."

"Liver and kidneys intact," he replied. "What more d'you want? Didn't you have intravenous feeding in your day?"

"Come to think of it," I said, "some one was trying out intravenous glucose injections. But the shock?"

"The thermos fluid was your old friend, Locke's solution. Plus the usual intravenous anesthetics. To this we have merely added α –, β – and γ – anti-shock hormone, a synthetic colloidal oxygen-carrier, synthetic prothrombin and streptosalvarsan. They'll probably drain him out in the hospital. Fill him from pooled donors. I believe his blood formula is $A_2C_1\delta\gamma$. On record. Subject to call."

"But lack of asepsis?" I insisted.

"Continuous lavage. Modern variant. Your Dakin's solution. The main thing to fear is the λ-group streptococcus. But here

And the henry slanted to the ground.

8

He shifted to surface transmission. We glided along a flower-bordered driveway.

"How about organ transplantation?" I asked. "One of our prophecies."

"Transplantation of certain simple tissues is part of ordinary hospital routine. Done, however, only after painstaking blood-grouping and quantitative horm-determinations. Organ transplantation, however, involves such prolonged delicate technic that it is rarely attempted, except in research."

The henry entered a park. Attractive bungalows. Venerable patients. One ancient, squatted in buddhistic pose on a rock, an electric light suspended a few inches above his head.

"Interesting case," commented the hormonologist. "Shaves and anoints his head daily. Sits for hours under his electric light. Perfectly happy. Picturing himself the second Tamalpais. We've merely substituted electricity for his original 'sacred lamp'."

We passed through the senile colony to an imposing group of buildings in the rear.

"Desenilization hospitals," he said.

"Desenilization," he explained later, "had its inception in the 2313 Los Angeles epidemic, following the introduction of a group of natives from Tibet. The epidemic was characterized by a rapid shrinking and jellification of the body. Particularly marked in the bones. Before death, the patient was often reduced to half his initial height."

"Sounds like some of our war infections," I said.

"The disease was transferred to rodents," he continued, "and was propagated in rats, for nearly two hundred years, before the causative agent was isolated and cultivated. From pure cultures of this microorganism a series of highly specific hystolysins were finally isolated. One of these is almost absolutely specific for degenerated cells, particularly of the connective tissue groups."

"Desenilization," he added, "is usually attempted between the sixtieth and sixty-fifth year. There are two stages. First, a gradual, careful desclerosation of the body, by daily, intravenous injections of hystolysin. Followed by a forced multiplication of residual normal cells by prolonged cross-circulation with a rapidly-growing youth.

"The process usually takes about a year. Is attempted only in carefully selected cases. Early attempts with advanced arterio-sclerotic types gave disastrous results. At the end of the process the individual is restored to about two thirds his original height.

Has about a third his original muscular strength. But usually has distinctly, often markedly restored special senses and mental vigor."

"The average duration of mental vigor," he continued, "is increased about fifteen years by the process. The average life-expectation, about five years."

"How often can the process be repeated?" I asked.

"Repeating the process five to fifteen years later produces such slight improvement in mental condition that it is no longer attempted."

"Desenilization is open to all," he explained, as we drove back toward the entrance. "It is, of course, expensive. But special provision is made for the free desenilization of individuals of outstanding mental attainments. The present much-beloved President of the Nordic Union, for example, was desenilized in this hospital, free of charge, about seven years ago."

(*To be continued*)

THE CONTENT OF SYSTEMATIC BIOLOGY

By Professor G. F. FERRIS

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THOSE who are confronted merely with the printed title of this paper will doubtless be justified in wondering which of the two possible pronunciations and consequently which of the two possible meanings of its second word it is my intention to employ. This apparent ambiguity is intentional, for I am really concerned with both. It is my hope that by a discussion of what I conceive to be the con′tent of systematic biology I may in some degree disturb the content′ of systematic biologists.

One whose biological interests happen to center chiefly about the problems with which the systematist is concerned can scarcely have failed to observe that systematic biology is somewhat in disrepute. Or at least if he has not himself detected it he will have had it impressed upon him by others who profess to have done so. In fact, the observation is one that it seems none but the most unobserving can avoid. There are certain national scientific societies of an honorary character to which no one can gain admission on the basis of systematic work alone, although scientists whose qualifications are chiefly literary and journalistic may be admitted into the circle of the elect. There are universities that will not grant the doctor's degree as a reward for systematic work, although they will grant it for other work that to the doubtless prejudiced eyes of a systematist appears to be of no very great significance.

And so, with the frequent repetition of this observation—a sort of reverse Couéism, as it were—the systematist, if he be not either strong-minded or supremely indifferent, may come to be somewhat depressed by it. He may finally conclude that his own field has but poor pickings and turn a longing gaze toward those other and still verdant pastures where for the moment there disport the dainty Drosophilas or where parades the proud pH. Worse than this is the fact that the younger men, casting about for their particularly fitting niche in the scheme of biology, are not likely to look with any marked favor upon attaching their roots in such a sterile field.

Now, what can the systematist do about all this? Of course the simplest thing that he can do is to give up being a systematist. He may grow a few flies or a few silkworms or perhaps a few flowers or whatever else is convenient, find out what a chromosome is and what "crossing over" and "linkage" mean and call himself a

geneticist. He can go out into the fields and engage in any one of several delightful and harmless activities that will permit him to intrude within the society of the ecologists. Or he may elect any one of several other more or less similar means of escape that will readily suggest themselves to one who desires above all to swim with the current.

But if he refuses to forswear his faith and elects to remain a systematist, if he is able by some such arguments as I have elsewhere presented to revivify his belief in the worthwhileness of his activities, what is there that he can do to aid in the elevating of his work in the estimation of other biologists—or as some might maliciously prefer to put it, of biologists? We are of course all familiar with the copy-book maxim that it is not what people think of you but what you are that really counts, yet after all there is a certain amount of satisfaction in being appreciated.

In the first place, what is the common conception of a systematist? As I have gathered it, it may range among those who are not themselves systematists from a belief that he is an encumbrance upon the earth to a grudging admission that such work must be done by some one. The latter is usually accompanied by a query as to why any one should want to do it. Some regard the systematist as a mere cataloguer. Others, disturbed by certain of his incidental activities, look upon him as a juggler of names. To some he is merely a man who describes new genera and species without end in order that he may delight in seeing his name printed after them in accordance with the quaint custom of his tribe. Some would unkindly remark that he is merely a pseudo-scientist, and I suppose that some day we shall have to debate the question as to what science really is.

What do systematists think of themselves and of the purposes and limitations of their work? After all, this is the more important. It is with their conceptions that I am the more ready to quarrel. We may cheerfully excuse those who from lack of acquaintance with our work do not understand or appreciate it. We can hardly be so lenient with those who do not understand or appreciate the possibilities of their own work. Here, it seems to me, is the real root of the difficulty. The systematists themselves—of whom I consider myself to be one—are to a great degree responsible for the present situation. They do not come into the court with clean hands.

I may perhaps misinterpret the views of systematists, yet my conclusions are drawn from their work. Apparently there are many who are indeed content with the mere recording and superficial describing of supposedly new species, to whom the title, "One hundred

species of something-or-other new to science,'' represents the very apex of achievement and this in spite of the fact that we already know far more species than we know what to do with. Apparently there are some who conceive their work as chiefly nomenclatorial and who regard systematic biology as synonymous with a system of names. Apparently the majority are content if they have described the more obvious external features of an organism and on this basis have made some attempt to allocate it in the system of classification.

These systematists are indeed working in a field that is destined to sterility. It is a field about which there exists a barrier through which the refreshing streams of thought from other fields may not penetrate. These systematists have drawn or have permitted to be drawn a rigid distinction between their own work and that of the geneticist, the physiologist, the chemist and the experimental biologist.

It is against this isolation that I would protest. Rather than to permit genetics or physiology or biochemistry to push systematic biology into the humble seat in the ashes where it shall sit for all future time as the Cinderella of biology I would urge that systematic biology reach out and appropriate unto itself the fine raiment of these sisters. After all, none of these things is an end in itself. They are all rather methods that can be applied to various ends. They can be utilized by the systematist.

There are really two things that the systematist is after. One of these is the purely practical aim of making it possible to identify species. Along with this, of necessity, goes the entire matter of naming and arranging species in some sort of order so that we may be able to talk about them. This aim can be attained after a fashion without much consideration of other factors and in many cases by means of the most artificial of characters and with a minimum of actual knowledge. Any one, for example, can tell a horse from a cow at a glance without being able to give any definite analysis of his reasons for separating the two and without being able to tell any one else how to distinguish between them. However, this describing and naming of species is an entirely legitimate and in fact a necessary aim. The unfortunate thing is that it is so often considered as constituting the whole of systematic biology or taxonomy and that even where it is the sole aim of the systematist that aim is so widely missed. In actual practice it constitutes a very large preponderance of the routine work of the systematist, even of the systematist who would avoid all routine if it were possible to do so.

Nevertheless, in addition to this mere identifying and naming of species there is still something else. This identifying and nam-

ing is merely knowledge without understanding. It is one thing to discriminate among species after we know them to be distinct, it is another to find valid reasons for our discrimination and to understand the relation of species to each other. Knowledge without understanding is perhaps not valueless—it is sometimes extremely dangerous—but it at least is an inefficient and a poor thing. Its consequences in systematic biology may be seen in the activities of a botanist who named two hundred species of a familiar western flower because of his religious conviction that species are immutable things, fixed since the creation, and that consequently two forms which are recognizably distinct can not come from the same ancestors! It is the kind of thing that appears all too frequently in systematic work, although probably from far less sincere motives than were those of the botanist.

The attainment of such understanding involves a great many things that need not, and in fact should not, be involved in the purely practical work of identification. For practical reasons the latter should be made as simple as possible. The attainment of the first may not be simple at all. Here the systematist should employ all the tools that are available and that can give him any aid. It is here that the methods of the comparative morphologist or anatomist, of the physiologist, of the geneticist, of the experimental biologist, even of the chemist may be brought into use. It is to include all these things that I would urge the extension of the conception of systematic biology. It is not the method utilized, but the aim that determines what our work is to be called.

Let me illustrate by actual examples.

There is a certain group of western plants that are extremely puzzling to the systematist. Whether there is but one species or whether there are several is a question that can not be answered on the basis of herbarium specimens alone with any degree of satisfaction. However, a botanist has attacked this group by way of the methods of the geneticist and has arrived at certain definite conclusions as to the number and the characteristics and the genetic relationships of the species involved. I can not see that this is any the less systematic work because it has been done in this way rather than in that which the botanical systematist ordinarily follows.

There is what is supposed to be a single species of scale insect which occurs on a wide range of plants, frequently becoming a rather serious pest in orchards. As far as structure is concerned apparently but one species is involved, yet in form and habit individuals from the various host plants present a wide range of difference and there is a very definite question—one that is by no means purely academic—as to what these forms are. One may con-

template the spectral remains of the insects as they appear when ready for study under the microscope indefinitely without any prospect of a solution. This solution of the question probably can be attained, however, by experimental methods involving the careful rearing and transference of specimens from one host to another. This is experimental systematic biology. As a matter of fact, work of this sort is very sadly needed, for there has long been doubt as to the effect upon insects of a change in host. There is very little valid evidence one way or the other, but no inconsiderable amount of the systematic work in certain groups has been definitely influenced by preconceived judgments as to what that effect would be. If the question can be settled by experimental methods the recognition of the species by the ordinary procedure will present no difficulty.

There is a group of scale insects from one species of which our entire supply of shellac is obtained. Altogether, there are about fifty species known in the group. Only a few of these produce a true lac, others produce something like lac, while still others produce a substance that has no resemblance to lac at all. Here there is room for the application of chemistry in the study of these forms. If a chemical study of the secretions of the various forms should reveal that each has a specifically recognizable secretion, would not that justifiably be acceptable as a contribution to systematic work? True, no one would wish to take the trouble to make a chemical analysis of the lac in order to identify a species, for they can be identified more easily by other means, but such chemical study would undoubtedly aid in that understanding of the relationships of the species which we should have for systematic purposes. The bacteriologist, it seems, actually must rely upon chemical reactions as a matter of routine procedure in order to identify the forms with which he deals.

Personally, I am convinced that there are such things as physiological species. After all, what are structural differences but the expression of some preceding physiological activity? If this be true, there must be forms which will differ in their physiology even if not in their structure. It may not be necessary or desirable to recognize these forms by names, but at least a physiological study of them would aid in a proper understanding of their relationship to one another.

I do not wish to be misunderstood as proposing that every systematist should be at once a geneticist, a physiologist, a chemist, a comparative anatomist, an experimental biologist. I do believe, however, that he should be one of these things at least and should

have some appreciation of the others. I do contend that the aim of systematic biology, that of discriminating among those myriads of forms of living organisms that we call species and of understanding their genetic relationships to each other is broad enough and well enough worth while to include under its aegis workers in all these fields.

I do not wish to be misunderstood as proposing that every species shall be subjected to genetical and physiological and chemical as well as structural analysis before it is given a name and described. Obviously nothing of the sort is possible with the millions of forms that occur in the world. There is in general no need of any such elaborate program, and for many years to come we can get along very well in the majority of cases with merely an adequate structural analysis and without being too curious as to the exact genetic status of our species. With the majority of species it is almost enough merely to know that they exist and can be recognized when the occasion arises. But when the occasion does arise and when anything at all is to be gained by the use of these other methods they should be used.

I would then maintain the thesis that if systematic biology will extend its definition of itself, if it will revise its estimate of itself, if it will in addition raise its standards of work, it will automatically deserve and, let us hope, regain the esteem of the workers in other fields.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

SUGAR FROM SUNFLOWERS

A NEW sort of sugar may soon be on the market that is sweeter and better and possibly cheaper than common sugar. I call it "new" because it is unfamiliar and not yet for sale in the shops, but as a matter of fact it forms a large part of our daily food already. The reader, if he be an ordinary person—though no one will admit that he is—is now consuming the new sugar at the rate of a pound a week and gets from it some six per cent. of his muscular energy.

The chemist knows of scores of different kinds of sugars, but the public knows only two, beet sugar and cane sugar, and these two are really one, sucrose, the chemist calls it. When we eat this sugar it is split up into two equal parts, one of which is known as "glucose" and the other as "fructose." The chemist, who analyzes sugars by passing a ray of polarized light through their solutions, calls the former "dextrose," or the right-handed sugar, because it rotates the ray to the right, and the latter "levulose," or the left-handed sugar, because it rotates the ray to the left.

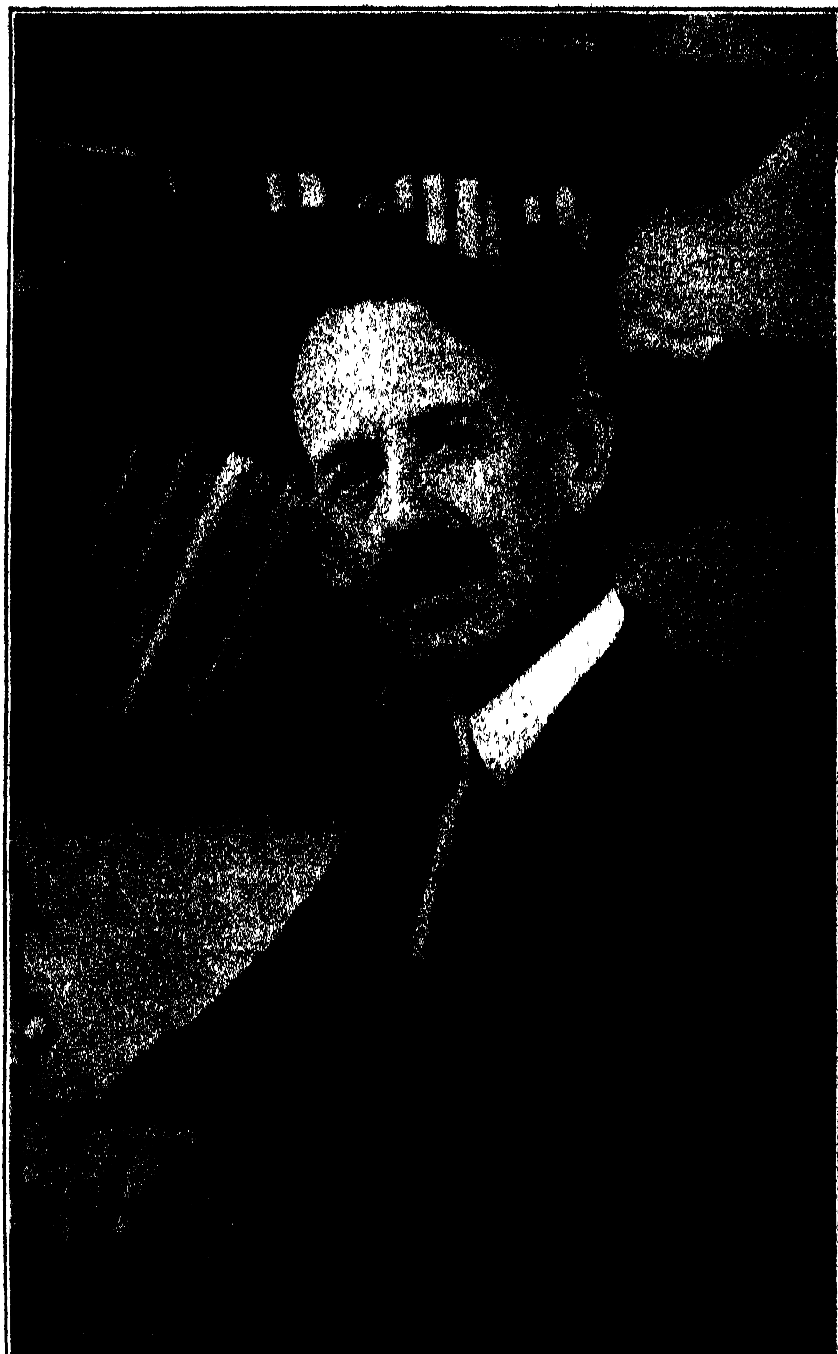
Now glucose or dextrose made from cornstarch has in recent years come into common use as a syrup for making certain kinds of candy, and can now be prepared as a pure white powder. But it can not completely replace cane sugar because it is not nearly so sweet.

The other sugar, fructose or levulose, has a sweeter disposition than either its twin, glucose, or its mother, sucrose. In fact, two pounds of levulose would go as far as three pounds of cane or beet sugar in sweetening food. It is also much more soluble than common sugar and so can make a sweeter syrup. A spoonful taken on the tongue vanishes like snowflakes in the sun.

Levulose gets its other names of fructose or fruit sugar because it occurs commonly in sweet fruits, as it does also in honey. But it has never been prepared in commercial quantities because of the difficulty of purifying it. This difficulty has at last been overcome by the researches of Jackson, Silsbee and Proffitt at the Bureau of Standards, who have worked out a process of producing it by the ton in a pure white, crystalline form. This may make levulose a formidable rival of common sugar, since it may be made from a plant that is tougher, wider spread and more prolific than either beet or cane.

This is the Jerusalem artichoke. The tubers of the artichoke are similar in composition to potatoes but, instead of the starch of potatoes, they contain a similar substance, known to chemists as "inulin." Starch, digested in warm acidified water, turns into the right-handed sugar, dextrose. Inulin, treated in the same way, turns into the left-handed sugar, levulose.

It seems that we can get more sweetness from an acre of soil by growing artichokes than any other crop. The average yield of potatoes in the United States is three tons per acre. In England this is doubled. But fifteen tons per acre of artichokes have been raised in Pennsylvania, using the strain known as the Mammoth White French Jerusalem Artichoke.



PROFESSOR HERBERT SPENCER JENNINGS

Henry Walters professor of zoology and director of the biological laboratory at the Johns Hopkins University, who is the first recipient of the Joseph Leidy Memorial Award of the Academy of Natural Sciences of Philadelphia.

In the midst of the Great War when England seemed in imminent danger of starvation through the cutting off of her shipping by U-boats, the British government set the Royal Society to finding what crop would produce the largest amount of food on this limited land. The War Food Committee reported, in "private and confidential circular No. 46," that the Jerusalem artichoke was better than potatoes, for it could be grown on waste land without preparation and with little cultivation, and that the yield in gardens ran up to 20 or 22 tons per acre.

Unlike the sugar beet, the artichoke is not impaired in sugar content by freezing, so the tubers can be kept in storage or left in the ground until it is convenient to work them up in the factory. The factory can therefore be kept running for eight months in the year instead of three with consequent reduction of overhead and investment.

The tubers yield ten to twelve per cent. of levulose. Formerly crystallized levulose was sold, or rather quoted in the catalogs of rare chemicals, at over a hundred dollars a pound. The new process may reduce the price to that of common sugar, or cheaper considering its superior sweetening power. It has one disadvantage that may interfere with its table use; that is, it absorbs water from moist air more readily than salt, and so is apt to deliquesce into a syrup.

So it seems that we need not depend upon imported sources for our sugar, the tropical cane or the European beet. The Jerusalem artichoke does not come to us from Palestine, but is a native weed, one of our wild sunflowers, that means that it is immune from destructive insects and dis- and needs but little encouragement to make a good crop.

MEASURING ACHIEVEMENT BY ABILITY

School teachers are at last beginning to see a way to remedy what has been hitherto regarded as an inevitable defect of the educational process, the appalling waste of the most valuable material in the world, the time, the efforts and the hopes of youth. Year after year as the teacher met the fresh faces in his college classroom he has been saddened by the thought that of these students, perhaps brought there by high ambition, perhaps sent there at parental sacrifice, a certain proportion must fail despite what all that they or he could do. They had all passed the entrance examination and possessed the minimum requirement of knowledge, yet neither he nor they could tell whether they were qualified for the tasks that would be imposed upon them in the next four years, or whether both would lose their labor.

Now, however, it is possible for a high-school senior to find out with a very high degree of probability what will be his success in college studies. The new examinations devised for this purpose are objective, comprehensive, fair and impersonal, and they test both the factors of success, training and aptitude. In one state over 1,500 students have now been followed through their third year at college, and their achievements, in most cases, come close to the predictions based upon these qualifying examinations.

Professor Carl E. Seashore, of the University of Iowa, in his address recently before the National Academy of Sciences on the discovery and motivation of the gifted student, called attention to the amazing magnitude and fixity of individual differences as disclosed by mental measurements. For example, one student may have ten or twenty times as good a memory for the shapes of things as another student has. Or the same person may have ten or twenty times as good memory for such geometrical forms as he

DR. EMIL ADOLF VON BEHRING

The distinguished German immunologist, discoverer of diphtheria antitoxin.

—From a painting by Klein-Chevalier

has for differences in the quality of musical tones. The accurate knowledge of such different aptitudes is of inestimable value in determining whether a boy or girl should undertake training to be an artist or a musician. Such knowledge can be obtained at a surprisingly early age and it is surprisingly persistent. As Professor Seashore says:

"The sense of pitch and the sense of rhythm, for example, may be measured early in childhood and are found to remain constant throughout life except for deterioration, normal or pathological, despite most elaborate education and special training. A boy who is quick and accurate is likely to be the man who is quick and accurate in any particular type of motor process. As our measures of intelligence are gradually improved, we find more and more evidence that the intelligence quotient of 75, 100 or 125 tends to remain fairly fixed throughout life, with or without extensive education of the individual."

On account of the infinite variety of individuals and the wide range of their capacity, it is manifestly unfair to require of them all the same amount of work or the same grades. It has been found that for an examination, which the upper quarter of the class should pass with a grade of 75 per cent., the passing grade of the poorest members of the class, if they made equal effort, should be set at 25 per cent. To set the same requirement for such unequal abilities in the classroom is as unfair to both extremes as it would be in the gymnasium to require them all to jump over a three-foot bar, which for some would be impossible and for others child's play. The new educational slogan, according to Professor Seashore, is "to keep each of the students busy at his highest natural level of successful achievement."

The present practice of whittling down square pegs to fit into round holes may in time be abolished by means of placement tests and vocational guidance. It is coming to be realized that all young Americans are entitled not only to the opportunity for education, but to the particular kind of education to which they individually are fitted for. The old Socialist motto, "From each according to his ability; to each according to his needs," is the motto of the new education.

THE QUESTION OF ETHER DRIFT

A DRAMATIC culmination of a controversy that has divided the scientific world for more than forty years was the appearance upon the same program of the National Academy of Sciences annual meeting of two papers which present new evidence on the question of Einstein's theory of relativity. The first paper was by the president of the academy, Professor A. A. Michelson, of the University of Chicago, whose historic experiments in 1881 first showed that there was something wrong about our traditional ideas of space and time, and so led to the Einstein theory. The second was by Professor Dayton C. Miller, of the Case School of Applied Science, Cleveland, who has recently repeated the original Michelson experiments on the top of Mount Wilson, California, and got different results which conflict with the Einstein theory.

The question at issue is whether there is an ether pervading all space and if so whether it is stationary or is carried along by moving matter.

All attempts to prove the existence of the ether or to measure "ether drift" through moving bodies have so far failed. The crucial experiment

MEMBERS OF THE NATIONAL ACADEMY OF SCIENCES

From a group taken on the steps of the U. S. National Museum, shortly before the death of Dr. Arthur G. Webster, professor of physics in Clark University, who is shown in the foreground on the right. On the left is Dr. Charles D. Walcott, secretary of the Smithsonian Institution, who was in April elected president of the American Philosophical Society, having already been president of the National Academy of Sciences and of the American Association for the Advancement of Science. Above are Dr. Robert G. Aitken, director of the Lick Observatory at Mount Hamilton, California; Dr. Francis G. Benedict, director of the Nutrition Laboratory of the Carnegie Institution at Boston; Dr. Robert A. Millikan, director of the Norman Bridge Laboratory of the California Institute of Technology; Dr. Franz Boas, professor of anthropology at Columbia University, and Dr. Frank B. Jewett, of the New York Telephone and Telegraph Company.

was that tried by Michelson in cooperation with Morley in 1881. He set up in the basement of the Case School a marvelous accurate instrument named the "interferometer," because it measures the interference of fringes, or black and white bands, produced when two beams of light come together in such a way that their crests and troughs conflict.

Besides rotating on its axis from west to east at the rate of a third of a mile a second, the earth revolves around the sun once a year, at a rate of 18 miles a second, and the sun with the earth and the rest of the planets is moving through space at the rate of about 10 miles a second. But whichever way Michelson turned the arms of his interferometer, he found no difference in direction and got no evidence of ether drift. He repeated the experiment in 1887 with more accurate apparatus and in the same place but still got negative results.

This seemed to prove that the earth did not move through a fixed ether. But to assume the contrary, that the earth did not move but was permanently at rest in a fixed ether, was inadmissible because that would upset Copernicus and all the astronomers since.

No adequate explanation of these two conflicting experiments was produced till 1905, when Einstein put forward his special theory of relativity which disregards the ether altogether. This theory carried with it such revolutionary consequences as to the nature of space and time that men began to question whether there might not be some flaw in the Michelson-Morley experiment, on which such a vast edifice of speculation had been built by Einstein and his disciples. So Professor Miller constructed a more elaborate interferometer apparatus with all possible precautions and refinements. When he tried it out in the place of the previous experiments, the basement of the building, he got the same result, that is, no adequate evidence of ether drift.

But a few months ago he set up the apparatus on the summit of Mount Wilson, 5,000 feet above the sea, and this time got a positive displacement of the fringes. If Miller's experiment is confirmed, it would indicate that the ether is somehow tangled up and carried with the earth at points beneath the surface, like the basement laboratory, but that out on a mountain top, somewhat away from the main mass of the earth, the ether does drift by, or through, matter to some extent. This means that we have in the ether a sort of fixed framework and can, in spite of Einstein, get evidence of real motion and not merely relative motion of the stars and the earth. There is then a definite clash between the results so far obtained by Miller and Einstein's special relativity theory.

But the paper read before the academy by Professor H. G. Gale, of the University of Chicago, giving the result of the new experiments by Professor Michelson and himself on ether drift accords with Einstein's theory instead of contradicting it. In this apparatus a divided ray of light was sent in opposite directions through a rectangular water-pipe over a mile long in order to see if the rotation of the earth made any difference on the speed of light in different directions. The measurements with the interferometer were almost exactly the figure required by the theory of relativity, and Professor Michelson in a preliminary announcement of the result in a recent public lecture in Chicago said: "Provisionally there is no question that the Einstein theory is correct and this experiment is one more striking confirmation of his brilliant work." But this result is also in accordance with the old ether theory so it does not definitely decide

THE MACMILLAN ARCTIC EXPEDITION

The map shows the course of the *Bowdoin* from Wiscasset, Maine, to Etah, and back to Nachbak Bay, Labrador. At Etah, the nearest inhabited spot to the North Pole, will be the headquarters of radio station WNP, through which Mr. Macmillan will send home news of the explorations through the National Geographic Society. An airplane base will be established at Cape Hubbard, whence the planes of the United States Navy will fly over the large unknown territory between Cape Hubbard and the North Pole, at both of which the flag of the United States has been raised. Airplanes will also undertake to make a reconnaissance of North Greenland, concerning the inland ice of which comparatively little is known. Nansen, in 1888, crossed Greenland directly from east to west. That cross-section was made, however, below the Arctic Circle where the island-continent is about three hundred miles across. Peary cut across the northwest corner in the nineties. The only other crossings were those of Rasmussen and De Quervain, each in 1912, and Koch, in 1913. The airplanes will also explore Ellsmere Island and Baffin Island and, on their return, parts of Labrador. Of particular interest, however, will be the exploration of the vast unknown region between Fort Barrow, Alaska, and the North Pole.

between them. Besides, this experiment was performed underground like those in the basement of the Case School and, if Professor Miller's experiments are right, different results may be expected on the mountain tops.

With the possible exception of Miller's recent results on Mount Wilson, the Einstein theory has been substantiated on all points open to experimental evidence. His prediction of a displacement in the position of stars close to the sun was verified by eclipse observations of Eddington, of England, and Campbell, of California. His prediction of a shift in the spectral lines from the sun was verified by St. John at Mount Wilson. The theory of relativity also affords an explanation of the irregularities in the orbit of Mercury, the distribution of the fine lines of the spectrum of light as calculated by Sommerfeld, of the results of the Michelson-Morley experiment and of the continued production of heat from the sun and stars by the conversion of their substance into radiant energy.

METHANOL

THE public should get acquainted with methanol, which they have hitherto known, if at all, by the name of "wood alcohol" or "methyl alcohol." Its new name—accent on the first syllable, please—will tend to prevent the frequent and sometimes fatal confusion of methyl with her sister ethyl, who is the more sought after and less deadly member of the family. Many a man has asked the druggist for "alcohol" for horse-liniment or cleaning his typewriter, and the druggist, not noticing the wink, has given him the kind of alcohol that makes a man drunk blind instead of blind drunk. Alcohol for industrial purposes is often denatured with methanol and when it is de-denatured for beverage purposes some of this is likely to be left in. Because of such accidents conscientious bootleggers are said to furnish free with each case of their whiskey a bundle of pencils and a card, "I am blind," so that the purchaser is insured of a livelihood in case of the worst.

Methanol in its proper place, which is outside the human stomach, is a useful article in many manufactures and some eight million gallons have been made in America annually by the distillation of wood. But this method of manufacture is now hard hit by a new process which uses coal and water as the raw material. The first step in the process is the formation of the well-known "water-gas" by passing steam over hot coal. This gas is a mixture of carbon monoxide and hydrogen, both good combustibles. When the water-gas, mixed with more hydrogen, is subjected to heat and pressure in the presence of a catalyst the carbon monoxide and the hydrogen combine to form methanol.

This synthesis is similar to the Haber process which combines the nitrogen from air with hydrogen from water gas to form ammonia. By means of the Haber process Germany has been supplied with fixed nitrogen for explosives in war time and fertilizers in peace time.

The new process may prove to be equally important since by slight variations the same raw materials may be made to yield acetone, a useful solvent, formaldehyde, a familiar disinfectant, and an oily mixture, resembling petroleum, from which gasoline may be made. The demand for formaldehyde has greatly grown of late because it is one of the two ingredients of synthetic resins, such as bakelite, which give us music by means of radio receivers and phonograph records. Methanol is being increasingly employed as a solvent in lacquers and the like, and is used in making many dyes and drugs.

The inventor of the methanol process, Dr. Franz Fischer, director of the Kaiser-Wilhelm Institute at Mulheim-Ruhr, is now in this country and gave a talk at the recent Baltimore meeting of the American Chemical Society. In his process he puts the mixture of hydrogen and carbon monoxide under a pressure of 1,050 pounds per square inch at a temperature of 410 degrees Centigrade. The catalyst, that is, the agent that effects the combination of the gases, is zinc oxide. The Badische plant at Merseburg turns out twenty tons of methanol a day.

The basic Badische patent on this process was granted on October 17, 1916, in the United States. When we entered the war this was taken over with the other German patents by the Alien Property Custodian and transferred to the Chemical Foundation, which grants non-exclusive licenses to American manufactures. Later developments of the process have been patented in Germany and France in 1923. The French experiments have been carried out by M. Patart with the aid of the Ministry of Commerce and Ministry of War, and are described in *Industrial and Engineering Chemistry* of April, 1925. It is estimated that synthetic methanol may be made by this method at about twenty cents a gallon, which is less than a third of the present American price for the product of wood distillation.

CORRESPONDENCE

THE GOVERNOR OF CALIFORNIA AND THE REGENTS OF THE STATE UNIVERSITY

To the Editor of The Scientific Monthly:

The Scientific Monthly for April, 1925, page 417, publishes the following from the anonymous pen of "The Research Worker, Stanford University":

"Look at the governor of California refusing to endorse modern hygienic measures for fear of alienating the Christian Science vote. The regents of our state university (of California) denying adequate appropriation to the medical department for fear of antagonizing the Protestant religio-therapeutic bloc."

I have no right to speak for the governor of California, but undoubtedly my relations with him are more intimate than are those of "The Research Worker." In my opinion, California has a courageous governor, who acts in accordance with his own conscience, and without reference to capturing or to alienating the votes of any group.

As a result of my intimate relationships with "the regents of our state university," in the past two years, I have encountered no fact, or even the remotest suggestion of a fact, which "The Research Worker" could make the basis for saying that the regents are paying any attention to any "bloc" of voters, religio-therapeutic or otherwise. I am convinced that a little bit of "research" would have saved "The Research Worker, Stanford University" from assuming the unenviable position of publishing anonymously a libellous statement concerning the governing board of another university.

W. W. Campbell,
President of the University of California

Berkeley, California,
April 29, 1925

[No journal is responsible for the opinions expressed in the articles that it publishes. The editor of this particular journal, being a psychologist by profession, would hesitate to ascribe motives for any action, whether it be of a governor of a state or of a research worker, except as a working hypothesis formed from the total behavior of an individual. This, however, is not the usual procedure, and men are hung or elected president of the nation on the supposition that we know the motives that have led to their actions. In a democracy it is desirable to allow free expression of opinion concerning those elected to public office.—EDITOR.]

CHRISTIAN SCIENCE

TO THE EDITOR OF THE SCIENTIFIC MONTHLY:

It is regrettable to find a publication such as THE SCIENTIFIC MONTHLY lending itself to a malicious attack upon the religious teachings and healing ministry of Christian Science. This I may add is especially true in respect to an offensive article appearing in your April issue where the writer hides his identity behind a *nom de plume* but openly trades upon the good name of a well-known university. This person, whoever he may be, writes as one completely blinded by a bitter prejudice and what is more, he proceeds with a flagrant disregard of demonstrated results to malign a great religious organization and cast reflections upon the integrity of the multiplied thousands who go to make up its adherents. It is one thing to disagree with the teachings of Christian Science; but quite another to deliberately accuse Christian Scientists of falsity and misrepresentation. I, of course, recognize it as the privilege of your contributor to express his opinion regarding Christian Science, but I must deny his right to misrepresent the purposes of the Christian Science Church and publicly impugn the motives of its members.

His statement, for instance, that published testimonies of Christian Science healing were untrue and that the efficacy of Christian Science treatment had been adversely reported upon after an impartial investigation is wholly without warrant. Numerous committees have been appointed by religious and medical organizations to investigate so-called faith healing and the various modes of suggestive therapy, all of which are, however, the very antithesis of Christian Science teaching and practice. For your information I may say that the Christian Science Church uses the greatest measure of care in investigating testimonials of healing before they are published in the authorized periodicals of the movement. Such testimonies are certified to by at least three responsible persons.

I may also add that practically every known form of disease, including those diagnosed by responsible medical practitioners, has been successfully treated in Christian Science. I have on file in my office testimonies from dependable citizens of this state gratefully acknowledging the healing of disease diagnosed as organic by reputable physicians and in many instances pronounced incurable. Interesting enough, at or about the time our critic's article came to my desk a much respected lady of this city delivered to me a written testimony of her healing of cancer through Christian Science treatment. The lady's brother, a prominent business man also of this city, joined his sister in certifying to the healing. Such practical demonstrations have served to make a profound impression upon a substantial wing of the medical profession itself. As an example, Dr. Richard C. Cabot, of Harvard University, one of America's best known and most highly re-

spected medical authorities, has said, "We are firmly convinced that Christian Science has done and is doing a vast deal of good not only as a religion but as a health restorer and a protest against the short-sighted naturalness of the doctors." Equally interesting is the following statement from Lt.-Col. Frank T. Woodbury, M.D., of Edgewood Arsenal, "Every day we hear people remark that they had been given up by several physicians and finally went to a practitioner not of the regular medical school and were cured. I formerly thought that it was a case of exaggeration or of self-delusion, but I feel that we can not dismiss these testimonies with a learned bromide. The results of irregular practice are all around us. Ten Christian Science Churches in New York City alone [there are actually thirty-one] can not be blown away with a laugh. We have to admit that these sects and cults possess a knowledge of healing which we do not recognize." If space permitted almost countless citations such as the foregoing could be offered as evidence that a substantial number of physicians who occupy ranking positions in their profession wholly disagree with our critic's attitude towards Christian Science.

In view of the seriousness of your contributor's misrepresentations I respectfully request that you publish this correction without delay.

Sincerely yours,

CHARLES E. HEITMAN,

Christian Science Committee on Publication

NEW YORK, N. Y.,
APRIL 30, 1925

[WE have received a number of letters objecting to the criticism by "The Research Worker" (who is a distinguished man of science) of the medical activities of Christian Science and print one that claims to be official. Dr. Cabot may be correct in holding that "Christian Science has done and is doing a vast deal of good not only as a religion but as a health restorer" in so far as it teaches its adherents to forget minor ills and to be hopeful in regard to the future. But when it is officially claimed by Mr. Heitman that Christian Science cures practically every known form of organic disease, including cancer, then it is no longer a question of the attitude of scientific men on the validity of such claims, but only to what extent the law should be invoked for the protection of the incompetent.—EDITOR.]

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